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# ANNUAL REPORT
# 1956

# INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION

FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE

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# STRENGTHENING THE RESEARCH EFFORT

In introducing the annual report of the Intermountain Forest and Range Experiment Station for 1955, the Golden Anniversary of the Forest Service, major problems and opportunities in the next 50 years of forestry were noted. It had been a year of taking stock and of establishing goals for the future. A concluding statement read: "Although the general goals of wild land management have become clear, many methods and procedures, principles, and concepts must be worked out by the scientific method before these goals can be reached." The stage was set for a critical review of our research organization. How well equipped were we to carry on the research program needed to meet our goals? Just where was our investigative effort most deficient and what spots were most in need of strengthening?

In 1956, the first year of the second half-century of Forest Service activity, the Department of Agriculture launched most appropriately a study of the program of each of its research agencies. An integral part of the review was the preparation of a 10-year plan of increased effort to meet adequately the most pressing needs for research. This Station prepared, as its part of the project, an analysis of the most urgent forest land problems of its area and outlined a program to cope with them. As a sequel to last year's "look ahead" in terms of expected progress and future goals, it seems desirable to sketch here very briefly some of the outstanding elements in a program designed to make the first decade of the second 50 years a period of notable progress.

A number of our major forest land problems cut across all or many of our research divisions. One logical way, therefore, to classify research program deficiencies in this category is by vegetative cover type. Using this approach the major resource management needs in the Intermountain Station area may be arrayed as follows:

Guides for wise use of ponderosa pine lands.

Understanding the proper relationship of grazing use, erosion control, and water yield of mountain herblands.

Better management of western white pine and associated species.

Management and utilization of Intermountain lodgepole pine.

Erosion control and forage improvement on sagebrush-juniper range.

Improved guides for western larch--Douglas-fir management.

Protection and management of interior Douglas-fir.

Learn the silviculture and protection of Engelmann spruce-subalpine fir.

Restoration of east Sierra pine-brushlands.

Management of mountain brush.

Grazing management of cheatgrass.

Management of aspen-fir.

Grazing management and erosion control of salt-desert shrub.

Erosion control and forage production in southern desert shrub.

In the case of some of the above needs substantial research is now under way, while in others virtually nothing is being done. But regardless of the present level of activity and accomplishment, a greater research effort is required right down the line.

In strengthening to meet these 14 major cover type problems, what are the particular areas of research towards which each of our resource management divisions should direct its special efforts?

In Forest Management Research increased emphasis must be placed on establishing new forests of better quality through natural regeneration, planting, and genetical improvement as virgin stands are cut over. More effort must be directed towards developing proper management practices for existing young stands. Old-growth forests are important and should be given continuing study, but to meet the "goals of tomorrow" more research effort must go into the "trees and stands of tomorrow." The many mensurational needs deserve prompt attention and more basic silvical studies must be provided.

Range Management Research must devote more attention to game-habitat investigations and to developing a greater understanding of the ecological basis for using and maintaining grazing lands. It should devise ways and means to restore grass and herbaceous cover to denuded ranges, to increase forage productivity, to lessen the dominance and spread of undesirable species, and to obtain maximum use consistent with control of erosion.

Watershed Management Research must redouble its efforts to learn how to reduce sediment production and increase water yield. More specifically it must determine how to minimize summer floods from torrential rains and winter snow melt floods; measure water use by different cover types; develop methods of maintaining the stability of loose soil on steep slopes under the impact of logging and grazing disturbance; and strengthen its watershed studies to evaluate the effect of different productive, protective, and corrective treatments.

Forest Utilization Research must give more emphasis to new and enlarged uses for Intermountain tree species. One promising field lies in the more complete utilization of forest and plant residues. It must concentrate greater effort on developing adequate harvesting methods for Intermountain forests, particularly for stands growing on steep, erosive slopes. The Station should do more than it is in evaluating existing log and tree grades and in providing leadership for their further expansion and use.

Throughout all the Intermountain forest types Forest Fire Research should strengthen its endeavors on logging slash control, general fire hazard reduction measures, fire prevention, studies of fire effects, and fire suppression methods. It must play a leading role, also, in developing techniques for the prescribed use of fire in forest management.

Insects are a serious concern to forest managers in the Intermountain Station area. Forest Insect Research must enlarge its studies of the ecological relationships and factors affecting the rise and fall of epidemic populations of such insects as the Black Hills beetle, mountain pine beetle, spruce budworm, and Douglas-fir beetle. With regeneration such a critical factor in forest management in the area and treatment of young stands becoming so important, studies of the pine engraver beetles which attack seedlings, saplings, and poles, and insects which damage cones and seed must be undertaken. The ultimate goal is the substitution of biological and silvicultural control for the more costly direct control measures.

Losses to forest diseases are very heavy in both the Northern and Intermountain Regions, but disease surveys must be strengthened considerably in order to assess such losses properly. Forest Disease Research should devote much greater effort in particular to the dwarfmistletoes, needle blights, pole blight and blister rust of western white pine, and a number of other pine rusts.

Some of the most highly specialized research needs lie in the field of forest protection. Because of the extensive forests in the Intermountain Station area and the tremendous distances between them, it is imperative that better insect and disease survey methods be developed to insure maximum coverage with minimum effort. Specialized needs in fire research are so numerous that they cannot even be enumerated here. One of the most spectacular and deserving projects, however, is that of weather modification, in which possibilities of preventing or reducing the severity of lightning fires are being tested. This and other urgent fire, insect, and disease problems require special laboratory facilities for effective study. A forest fire research laboratory at Missoula,Montana for basic studies of atmosphere, fuels, and model fires and for developing and testing methods, techniques, instruments, and equipment would greatly increase the effectiveness of this phase of the Station's program.

Forest Economics must provide the analyses to determine how far forest managers are justified in going to obtain regeneration, what intensity of protection against fire, insects, and disease is practicable, and which harvesting and cultural systems are most profitable. Economic analyses are needed, as well, to weigh the costs of special range and watershed treatments against the values to be derived. Economic studies to facilitate sound industrial expansion are urgently required now that the timber resources of the Intermountain Station area are being tapped more and more heavily. Forest products marketing research is an accompanying need.

A final and very special word should be said for the Forest Survey. Wise management of our forest resource depends in large part upon the accurate knowledge of its extent and condition which can come only from a sound inventory. To secure this vital information more quickly, we must step up the development of aerial photo interpretation, forest inventory techniques, and aerial photo coverage, and speed up the actual measurement of samples. The pressure of industrial development demands that reliable information on our forest resource become available in the near future. The Forest Survey must be expedited.

In preceding paragraphs some of the more noteworthy problems and needs for future research have been portrayed. It is well to look ahead, to analyze requirements and opportunities in the years to come, to establish goals, and to outline the measures necessary to attain them. Planning for the future, however, has little substance unless accompanied by sound and substantial current accomplishment. That progress was made on a number of Intermountain fronts during 1956 is illustrated by the divisional statements which follow in this report.

## FOREST MANAGEMENT RESEARCH

In the area served by the Intermountain Forest and Range Experiment Station, as in other parts of the country, early efforts in Forest Management Research were directed at old-growth forests. Their high value and overmaturity attracted the research forester to them just as surely as they drew the logger and forest industry. The primary need was to develop methods of harvest cutting which would remove the crop economically, secure adequate, desirable reproduction, and satisfy the other requirements of good silviculture, and still meet the demands for forest products over a period long enough for young stands to reach merchantability. It was a large order that has in the past commanded the major attention of Forest Management Research and will continue to hold a vital place in the Station's program for some time to come. Much of the knowledge gained from studying old-growth stands will apply, also, to young stands as they reach maturity.

But important as the old-growth forests may be, the real future of forestry lies in establishing new stands promptly after harvest cutting and providing for their maximum development, in restoring to productivity forest lands lost in the past due to fire, insects, disease, and brush invasion, and from improving tree quality through genetics. As rapidly as it can be accomplished without loss of value from established experiments, Forest Management Research is moving its emphasis to studies of reproduction and young stands. A greater proportion of effort is now going to research projects involving basic tree studies, regeneration (establishing new forests by natural or artificial means), intermediate cuttings (cultural measures in young stands), and genetics (improvement of trees and stands by selection and breeding). It is a logical development as forestry in the United States moves from its early exploitative phase into the intensive management of young, growing forests.

We are indicating the shift in emphasis that is taking place by the statements of accomplishment highlighted in the Forest Management Research section of this report. All of the items which follow were selected from the fields of regeneration, managing young stands, and genetics, although most of our effort is still with old-growth stands.

## REGENERATION

### Shade is Beneficial to Engelmann Spruce Initial Seedling Survival

Recent cuttings in the Engelmann spruce type to control the Engelmann spruce beetle have opened up many stands in the northern Rocky Mountains. Some of the areas on which clear cutting was imperative are not reproducing satisfactorily despite good seed years in 1952 and 1954. Special measures such as scarification with brush blades on bulldozers and prescribed burning have been taken to provide bare mineral soil seedbed and reduce competition by low vegetation. Also, seed trees have been left wherever possible either on the cut-over areas or as surrounding uncut timber. Large numbers of new seedlings have appeared in the spring but very heavy mortality has taken place in mid- and late summer, particularly on the clear-cut areas. A study of first-year seedling survival shows that insolation, even on north and east slopes of moderate gradient (19-28 percent) is an important cause of seedling loss which can be reduced by shading the seedbed.

Seedling mortality and survival were observed under several treatments in an effort to determine the causes of loss. The treatments were:

1. Shading (about 50 percent shade provided with laths)
2. Watering (during the critical season to prevent drought. Soil samples taken at weekly to 10-day intervals showed adequate soil moisture in the top 3 inches of soil all summer, so heavy watering was not necessary.)
3. Weeding (periodic removal of invading vegetation)
4. Control (seeded but nothing else)

All plots were seeded immediately following the disappearance of snow on scarified seedbed and mortality was observed and recorded at frequent intervals. Maximum soil surface temperature was determined by means of "tempils$^{O}$" (wax pellets made to melt at different temperatures).

High soil surface temperature which resulted in heat girdling of seedlings proved to be the greatest single cause of seedling mortality, accounting for from one-quarter to two-thirds of total mortality. Soil movement resulting from high-intensity summer rains was next in importance, causing seedling loss by washing seedlings out of the ground where soil was eroded and smothering seedlings where soil was deposited. Cattle trampling and drought loss followed soil movement in importance.

The principal benefit of shading resulted from reducing heat girdling, most of which occurred from about mid-July to the first part of August. During that period a considerable portion of the seedbed surface frequently reached or exceeded the lethal temperature (approximately 130° F.) for spruce seedlings. Beneath the lath shades the duration of the high lethal surface temperature was brief on any given spot. The high soil surface temperatures on unshaded plots were maintained for much longer periods of time causing more mortality from heat girdling.

Shade had no noticeable effect upon drought losses, most of which occurred where the seedling roots penetrated small pieces of rotten wood and debris beneath the soil surface and where the root penetration was interrupted by rocks close to the soil surface. Seedling root penetration averaged less than 3 inches during the first growing season. Differences in soil moisture in the top 3 inches of soil on the shaded and unshaded seedbed were insignificant because of frequent and well-distributed summer rains (4.72 inches between June 12 and September 9). If the soil moisture situation had been more critical, shading might have caused differences in drought loss.

Weeding or the removal of competition had no significant effect upon survival. Here also the effect of competition might have been more noticeable if the soil moisture situation had been more critical.

The micro-climate on seedbeds in spruce clear cuttings is severe and this study, although inconclusive, does point out the need for shade in seedling survival. To provide the needed shade in regeneration cuttings it may be necessary to keep clear cuttings small enough for shading from the side, to practice strip cutting oriented in an easterly and westerly direction, or to leave some slash and debris on the ground.

## Regeneration Studies at Boise Basin Experimental Forest

Studies in artificial regeneration of ponderosa pine on the Boise Basin Experimental Forest were pursued vigorously during the year. To supplement the Town Creek planting (described in the Station's annual report for 1954) a small test was made on the Headquarters site of the experimental forest. Two types of mulching (sawdust and pie plates), with half of each area sprayed to knock down competing vegetation, and planting holes dug by a power saw with post-hole drill attachment have proved successful so far. The power auger produces holes deep enough for proper planting of trees with long roots (over 14 inches) and is fast and easy to use. Two hundred holes per hour can be dug with it. Careful tamping was found to be a requisite for high survival.

After earlier preliminary trials, several kinds and sizes of paper containers are being used in quantity to test the usefulness of container planting on severe sites. The plan is to set out in the field both container and seedling, thus avoiding disturbing the roots. Perhaps by insuring quick deep penetration of the taproot, mortality due to lack of moisture and insolation may be avoided. A special rodent- and bird-proof shelter with watering facilities was constructed for the purpose of raising the seedlings in containers. No outplanting was done in 1956, but it is planned to continue the project during the coming year.

## Red Squirrels Cause Ponderosa Pine Cone Loss

During the year a study of the impact of red squirrels on ponderosa pine seed crops was completed on the Kootenai National Forest in northwestern Montana. Four successive cone crops were studied by climbing eight mature ponderosa pine trees three to five times a year[1/] and noting the number of cones cut by squirrels. Records were also kept of other factors causing mortality of cones. In the course of the study, the development of 1,109 female flowerbuds was followed. The four cone crops from 1953 to 1956 were rated either poor or fair. No good or excellent crops occurred during these years.

Red squirrels cut from 30 to 98 percent of the ponderosa pine cones maturing annually, or an average of 66 percent of the maturing cones in four successive cone crops. Additional mortality was sustained each year prior to the period of cone ripening by the loss of 1-year-old conelets incidental to the cutting of branches with mature cones and the cutting of branches without mature cones.

Considering all causes of mortality from flowerbud formation to cone maturation, red squirrels account for a much lower percentage of cone loss. This is so because of heavy first-year loss, principally through abortions, and also because of the relatively small amount of cutting when cones are in the immature or conelet stage (the first year and early part of the second growing season).

## Controlling Squirrel Damage to Ponderosa Pine Cone Crops

Cone and branch cutting on conifers by tree-climbing squirrels occurs in many forest regions throughout the country. In western Montana the red squirrel /(*Tamiasciurus hudsonicus richardsoni*) (Bachman)/ is the only known species that cuts seed cones and branches of ponderosa pine. Attempts by foresters to obtain

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[1/] The number of trees was reduced to six for the 1956 cone crop.

successful natural reproduction of ponderosa pine continue to be hampered by these animals, especially during the years of poor to fair seed crops. That the cone cutting reaches substantial proportions has been shown in the preceding item.

A promising method for controlling tree climbing and seed cone destruction by red squirrels has been developed and tested by the Intermountain Station. A sheet of smooth aluminum 18 inches wide, nailed in a continuous band around the trunks of isolated ponderosa pine trees, at a height of 5 to 7 feet above the ground, prevented squirrels from climbing. In the same test, bands 12 inches or less wide were ineffective.

Preventing squirrels from climbing seed trees, however, is only part of the problem. Squirrels can jump into the crowns of trees protected with bands from nearby unbanded trees. To determine how far these animals are able to jump when foraging for food under natural conditions, different "crown isolation" distances were tested.

It was found that 5.3 feet of "crown isolation" prevented squirrels from jumping from unprotected (unbanded) to protected (banded) trees. However, since squirrels under escape conditions have been observed to jump 7 feet horizontally and to span 10 feet in a diagonal jump with a drop of 12 feet, further tests are planned. Under normal conditions, 7 to 8 feet of isolation should give a high degree of protection.

Further studies are planned, also, to investigate possibilities of reducing the cost of banding by the use of cheaper material than aluminum and by faster methods of band attachment to the trees.

## Young Ponderosa Pine Trees Show Best Response to Seed Production Stimulation Measures

A small test of methods of stimulating seed production in Montana trees of all ages showed some response to stimulation in the first crop developed since treatment. Moreover, the data indicate that young trees which might not have produced a crop were stimulated to produce quite a few cones. Table 1 gives the results on Keen age class I, II, and III trees for partial girdling and on young trees for the continuous knife-cut girdle.

Table 1.--Total number of mature cones by age classes and treatment[1]

| Keen age class | Partial girdle | | Knife-cut continuous girdle | |
|---|---|---|---|---|
| | Treated | Check | Treated | Check |
| | Number | Number | Number | Number |
| I (50 years) | 108 | 1 | 106 | 4 |
| II (140 years) | 365 | 316 | - | - |
| III (220 years) | 633 | 380 | - | - |

[1] Based on 5 trees in each category.

Treatments were applied during late summer in 1954. The partial girdling was accomplished by removing a 1- to 2-inch-wide strip of bark around the tree except for a 4-inch bridge which was left intact. The continuous knife-cut girdle consisted of making a single knife cut through the bark and cambium completely encircling the tree.

While the continuous knife-cut girdle was applied only in the young age class (Keen age I trees), the results in that age class are similar to those in the comparable age class treated by the partial girdling method (table 1).

Tree vigor was not impaired seriously by girdling. In 1956, 2 years after treatment, only two trees, one Keen age II and one Keen age III, showed slight yellowing of the foliage. All the other trees remained healthy.

Further tests are needed to determine the response of older trees in a year of poor cone production.

## Results From Thinning Seed Spots

Sowing 5 to 25 tree seeds in small prepared spots often results in several seedlings becoming established. Tests of thinning seed spots were made in northern Idaho to determine the effect of density on height and diameter growth of the dominant seedlings. Spots sown to western white pine, ponderosa pine, and Engelmann spruce were included in the tests.

Nine-year results reported in 1948 showed that the number of seedlings per spot had little effect on height growth of seed spot dominants for any of the species tested. Heights of dominant seedlings of white pine and spruce increased very slightly with increase in number of seedlings per spot. Ponderosa pine showed a slight reverse trend. Diameter 1 inch above the ground line decreased for all species as numbers of seedlings per spot increased.

Additional observations made 16 years after sowing show that density has had a slight effect on height growth and a marked effect on diameter growth of dominant seedlings of all species tested. Both height and diameter growth have decreased as density increased. The effect on height growth of white pine and spruce is a reversal of earlier results while the effect on diameter growth is more striking than at the time of the 9-year analysis.

### Survival of White Pine Planting Stock in Grass-Sod

In the summer of 1954 the Development and Improvement Unit of Blister Rust Control tested the effect of five concentrations of Dalapon (2,2-dichloropropionic acid) spray on grass-sod and accompanying forbs and herbs. The Inland Empire Research Center cooperated with the Blister Rust Control unit to test survival of trees planted in the varying densities of grass-sod which resulted. Western white pine planting stock, 2-2, was used for the test in which 100 trees were planted in each of 12 plots (two plots of each of six spray treatments).

Results of the first year survival show no distinct relationship between survival and sod density. Survival at this stage of the experiment seems to be related to plot location, indicating a possible site difference which partially offset the effect of sod density. Later measurements may clarify the effect of grass-sod density on survival of the planted trees.

## Region 4--Intermountain Station Cooperative Studies

As agreed early in the year with National Forest Administration in Region 4 and as discussed in some detail in a timber management meeting of research, regional office, and national forest representatives, cooperative studies were initiated on six national forests during the year. Visits were made to the Boise, Payette, Targhee, Bridger, Uinta, and Dixie National Forests to examine problems, mostly of regeneration, on the ground and suggest either procedures for overcoming the difficulties or tests to determine a specific technique which would achieve a solution. Problems are evident in the ponderosa pine, Engelmann spruce-fir, lodgepole pine, Douglas-fir, and aspen types.

With regard to ponderosa pine, the success of the Town Creek planting project, which Research and National Forest Administration designed jointly, and the more recent good survival in plantations using Town Creek methods of stripping brush and planting in plowed rows together with careful handling of planting stock, have been heartening. Successful planting on the more severe sites still remains a major difficulty, however.

In the Engelmann spruce-fir type, it seems to be a question of cutting to create openings by groups or strips and scarifying the soil to induce natural regeneration. This is not always easy by virtue of steep topography or the presence of many boulders, but more commonly because most of the current spruce cutting has had to be in salvage operations of insect-killed timber which are not generally conducive to regeneration. Furthermore, the surface soil horizons sometimes dry out even where summer precipitation is generally common and heavy mortality of seedlings results, as occurred this year on the Aquarius Plateau of the Dixie National Forest.

Douglas-fir regeneration is mysteriously absent on certain areas. Careful examination has revealed no obvious reason for this deficiency but plans for testing of seed for viability and for trials of several cutting methods have been made in an attempt to learn the causes of this shortcoming and establish a successful technique.

Lodgepole pine cuttings have not always met with the same success of regeneration establishment as similar cuttings in Region 1. Insufficient scarification may be the chief cause. In a new sale on the Bridger National Forest it is planned to cut lodgepole pine in strips with various treatments of slash and several sources of seed for regeneration.

Aspen sales have increased sharply in the last year or so and at least four forests in Utah had sawlog sales in addition to cordage for excelsior. Aspen, regardless of age, will reproduce by root suckering but must be protected from browsing and plans are being laid to study the regeneration of the species by rotation of cutting and grazing areas. Because little is known on the subject in this region, there is a fine opportunity in these sales to test regeneration techniques and postlogging stand and young stand treatments.

Engelmann spruce seed lots from southern Utah were tested for viability and showed wide variation. Further tests of seed from Idaho, Wyoming, and Utah will be made in the early spring of 1957.

# MANAGING YOUNG STANDS

## Cleaning Western White Pine

Results from two sets of tests established in 1935 in Idaho on the Deception Creek Experimental Forest and on the Kaniksu National Forest show what can be expected from various types of cleaning and suggest possible improvements in the technique and scheduling of cleaning operations. In both cases an initial investment of 1 to 2 man-days per acre has resulted in greatly improved composition after 20 years. Additional benefits have been gained in the form of larger crop trees.

In the Deception Creek study a 16-year-old stand composed primarily of grand fir, western hemlock, and western white pine was weeded to form a nearly pure white pine stand. Less desirable species were left when no white pine trees were available. The test consists of three blocks of three plots each (two cleaned and one uncleaned). All cleaned plots were treated alike.

The dominant and codominant stand on the cleaned plots 20 years after weeding averaged 78 percent white pine compared with 23 percent white pine on the check plots, or a three-fold increase in the percentage of potential white pine crop trees as a result of the cleaning operation. The proportion of white pine in the complete set of plots would have been much greater had it not been for poor initial white pine stocking on one of the replications at the outset of the study. Here other species were substituted for pine in the selection of crop trees.

In addition to greatly improved composition, the cleaning has resulted in an increase in the size of the dominant and codominant trees. The average diameter of cleaned white pine dominants and codominants 20 years after weeding was 5.1 inches compared with 4.0 inches on the check plots. Dominant white pine on the cleaned areas averaged 4 feet taller than on the uncleaned areas.

The volume in dominant white pines on the weeded area accounted for 95 percent of the cubic foot volume of the dominant stand. On the check area, dominant white pines made up only one-fourth of the cubic volume of the dominant stand. The total volume of the dominant stand, including all species, was no greater on the cleaned areas, however. Considering all crown classes and all species, the check areas had 12 percent more cubic foot volume than did the weeded areas.

The Kaniksu plots, located in the Upper West Branch drainage of Priest River, test the development of white pine when released from a competing stand composed primarily of fast growing, intolerant western larch and lodgepole pine. Established when the stand was 8 years old, the test consists of three 0.4-acre plots each treated as follows:

Heavy cleaning--all trees except white pine and western redcedar were cut.

Moderate cleaning--all white pine and cedar were left. Larch within 8 feet of white pine trees were removed and Engelmann spruce and Douglas-fir were cut only when crowding white pine. When pine was absent, smaller larches were left and given an 8-foot spacing.

Check--left uncleaned.

The stand below 0.5 foot in height was not considered in the cleaning operation. Many small larches were left which subsequently outgrew the released white pine and reduced the effect of the cleaning operation, especially in the moderate cleaning. Nevertheless the white pine had fewer larches with which to compete.

Twenty years after treatment the percentage of white pine in the dominant crown classes was directly proportional to the degree to which the stands were cleaned. Less than 1 percent of the dominant trees on the untreated area was white pine as compared to 30 percent on the moderate cleaning and 61 percent on the heavily weeded plot. Although white pine was placed in a completely dominant position by the heavy weeding it gave up 40 percent of this advantage to larch and lodgepole pine in the 20 years after weeding. Most of this loss occurred during the first 5 years following weeding and could have been corrected at little additional cost by a followup cleaning.

Diameter and height of the dominants varied with degree of cleaning, also. Moderately cleaned white pine dominants averaged 4.2 inches in diameter and 29 feet in height, while unweeded dominants had an average diameter of 2.5 inches and an average height of 17 feet. Heavy cleaning increased the diameters to 4.6 inches and the height to 31 feet. On a percentage basis, heavy cleaning increased diameter of white pine dominants by 185 percent and height by 182 percent.

## Timber Stand Improvement on Boise Basin Experimental Forest

As a followup to the Ponderosa Pine Production Study, a major project reported in the last several annual reports, timber stand improvement work was begun on the sale area in 1956. The working plan provides for thinning, pruning, and improvement cutting in sapling and pole stands. During the period July 5 to September 28, two compartments and most of a third were thinned according to plan. Costs of various phases of the project were kept.

In conjunction with the stand improvement project, experimental plots are being established in each thinned compartment. Six plots to give detailed information on growth and yield were laid out and measured in 1956; the study plan calls for two plots in each compartment treated.

In cooperation with the Boise National Forest, slash from the thinnings was reduced in one compartment by the use of a chipper mounted on a D-7 tractor. Good disposal was secured, but the cost of chipping proved to be high.

For demonstration purposes two 1/5-acre plots in a 1935 plantation near the experimental forest headquarters were thinned in September by the crown method. Crop trees were pruned. In their 21 years of growth, the trees on the plots reached sufficient size and density for effective thinning and pruning.

This project will be continued next year.

## Three Tests of Precommercial Thinnings in Ponderosa Pine Stands

Three operations during the period 1933 to 1935 demonstrate what may be accomplished by thinning dense young stands of ponderosa pine in western Montana. Two locations and three average site and age classes were represented. The stands were thinned from below, removing suppressed trees and trees of poor form first. An unthinned check plot was reserved for each site class.

Twenty years after thinning, gross cubic-foot increment of the thinned plots exceeded that of the unthinned plots on all but the best site (site index 70). Had the check plot for this best site series been of more nearly normal density, these thinned plots might also have exceeded the unthinned check. Between degrees of thinning, both gross and net cubic-foot volume growth subsequent to thinning were not related to density within the range tested.

Trees which would have been left had the check plots been thinned were so designated on the plot records. The increase following thinning in cubic-foot volumes for comparable portions of the stands are shown in table 2. Similar trees in thinned stands grew from 135 to 317 percent more rapidly than did those on check areas. A similar comparison of diameter growths shows that much of this increased growth is the result of release of codominant crown-class trees.

Table 2.--Growth of comparable trees in thinned and unthinned ponderosa pine stands

| Site index | Degree of thinning | 20-year net increment after thinning | Cubic foot increment compared to unthinned plot |
|---|---|---|---|
| | | Cubic feet | Percent |
| 70 | Heavy | 1,453 | 135 |
| 61 | Heavy | 1,604 | 317 |
| | Moderate | 1,672 | 280 |
| 44 | Heavy | 900 | 187 |
| | Light | 900 | 138 |

These tests suggest that precommercial thinnings of ponderosa pine may possibly increase gross production in stands near normal density, materially increase diameter growth of dominant and codominant trees, and concentrate the productivity of the site on trees which will comprise the future merchantable stand.

## Commercial Thinnings on Woodlots in Second-Growth Ponderosa Pine

Five-year results from three tests of commercial thinning of sawlog material in 90- to 100-year-old ponderosa pine stands in the Inland Empire confirm at least in part the results reported last year from a comparable test. They also emphasize the fact that mortality, for the most part caused directly or indirectly by logging, often reduces at least temporarily the benefits of thinning.

Two of the tests, conducted near Usk and Colbert, Washington, confirm that light thinning, removing about 30 percent of the volume, improves the quality of the growing stock without sacrificing gross growth. In both tests net growth following light thinning was less than that of the unthinned stand because of greater mortality. Most of that mortality resulted from trees knocked over or broken off during logging and from bark beetles which thrived and increased in logging slash and trees weakened by logging damage. Mortality caused by logging usually is temporary, so that in the future, the thinned stands should retain a larger share of the gross growth.

Growth of the heavily thinned stands, from which 75 to 80 percent of the volume was removed, was considerably less than that of either the lightly thinned or unthinned stands.

Results from the third test, located near Tensed, Idaho, are incomplete since cutting was not finished in the stand marked for light thinning. However, growth data from that test were included in the analysis to permit comparison of heavily thinned and unthinned stands and to show the high growth rates that are possible on excellent ponderosa pine sites such as the one on which this test was located. Despite an average annual mortality of 292 board feet per acre, net growth averaged 408 board feet per acre per year. The Usk and Colbert tests were located on sites rated good and poor respectively.

## GENETICS

### Breeding Blister Rust-Resistant Western White Pine of Good Growth and Quality

The development of a blister rust-resistant western white pine is a joint project between Blister Rust Control, Region 1, and the Intermountain Station. Rust resistance aspects are the responsibility of Blister Rust Control. Major accomplishments in the vigor-quality phases which are a part of the Station's research program are described briefly below.

An intensive search during 1956 resulted in 123 new selections apparently resistant to blister rust, which make a total of 195 selections now available for study. Wind pollinated seeds were collected from as many of the new selections as possible and will be used for making a preliminary evaluation of both rust resistance and inherent growth capacity.

Routine measurements of growth rates of progenies were continued. The large amount of data being accumulated on growth of progenies up to 5 years of age and of their parents will soon permit an intensive study of the inheritance of this trait. Crown form data are likewise being accumulated. Recent developments include the use of current growth rather than total height in assessing juvenile growth in progenies up to 4 years of age. This seems to eliminate the need for seed weight adjustments in progenies beyond 1 year of age. The possible use of length of epicotyl (the portion of stem above the cotyledons) instead of total height in assessing growth rate of 1-year-old progenies is also being investigated.

A new flower induction test was installed this year in cooperation with the Pacific Northwest Station. Its purpose is to learn whether flowers can be obtained earlier on material grown on the northwest coast than in northern Idaho. Cones were found on trees as young as 7 years in that area. Such early flowering may be due to the longer growing season or to the occurrence of an early flowering race. The test involves grafting of seedlings into the tops of 10-year-old trees and planting as controls seedlings of the same northern Idaho origin in both localities. About 90 percent of the grafts were successful at the end of the first season and all planted seedlings survived to that time.

Physiological tests designed to aid in assessing inherent growth rate or other traits in the juvenile stage were continued. Preliminary results of a foliage dry matter content study showed that progenies of trees growing at a high elevation had more dry matter content (measured in early spring) than those of parents at lower elevations. Seed osmotic pressure tests, the possible utility of which was reported last year, are also being continued.

A report summarizing evidences of local ecotypes has been prepared for publication. It contains information obtained on juvenile growth rates, seed osmotic pressure, and to a lesser extent on foliage dry matter content of a large number of progenies of parents growing on different sites. Progenies of trees from better sites (moist, low elevations) usually grew more rapidly in early life when planted on good sites, and exhibited lower apparent seed osmotic pressures than those of trees on poorer sites (dry slopes or high elevations). Progenies of parents at high elevations had more foliage dry matter content and grew more rapidly when outplanted at high elevations than progenies of low elevation sources.

### Lodgepole Pine Hybrid Interplanting

A study designed to test and demonstrate interplanting as a practical method of the conservative use of hybrid stock was started in 1952. Five-year results show that the survival of hybrids[2] (*P. contorta* x *P. banksiana*) from a California seed source was 37 percent, and of indigenous nonhybrid lodgepole pine only 21 percent. Both rates of survival are below an amount satisfactory for successful plantation establishment without excessive fill-in planting.

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[2] The hybrids were developed by personnel from the Institute of Forest Genetics, Placerville, California, a branch of the California Forest and Range Experiment Station.

Height growth was also studied. Comparative heights 5 years after planting are as follows:

|  | Average total height[1] | Average maximum height[2] | Range of heights |
|---|---|---|---|
|  | Feet | Feet | Feet |
| Hybrids | .67 | 1.1 | .3 to 1.4 |
| Nonhybrids | .56 | .8 | .2 to .9 |

[1] Basis - 25 undamaged trees; difference not statistically significant.

[2] Basis - tallest 5 trees; difference significant at the 1-percent level.

Although survival is low the study will remain active and the trees will be examined at the end of 10 years to see if present differences in survival and growth rate are maintained.

## FOREST DISEASE RESEARCH

In introducing the following statements of progress in Forest Disease Research at Intermountain Forest and Range Experiment Station during 1956, it seems appropriate to say a special word concerning forest disease surveys. While not as well publicized or understood as other disease projects, they are vitally important. Surveys are essential to learn what diseases are present in the Intermountain area and something of their importance, to detect the presence of new threats, to appraise the extent and damage of known diseases for research planning purposes, and to delimit outbreak areas for control purposes. They are a necessary prerequisite to a comprehensive research program pointed at the forest diseases of highest priority.

Despite their importance, no forest disease survey has ever been conducted in Region 4 (the Intermountain Region). They are very deficient in Region 1 (the Northern Region), with a reasonably complete inventory of disease losses or conditions available only for pole blight and blister rust of western white pine. In any expansion of forest disease research activities, there should be provision for adequate surveys. Limited progress in this direction was made at Intermountain Station in 1956 by starting forest disease surveys of the dwarfmistletoes in Region 1.

Forest disease survey accomplishments as well as highlights of the Station's work with other disease problems during the past year are given in succeeding paragraphs.

### FOREST DISEASE SURVEYS

Distribution surveys of pole blight in western white pine were limited again in 1956 to examinations of previously uninfected stands. During the course of other field work many of the healthy white pine pole stands on the Colville National Forest in Washington were reexamined for the presence of pole blight. There was no evidence of the disease. On the other hand, the area on the Clearwater National Forest reported as doubtful in 1955 was confirmed as having pole blight this year. It lies outside the previously known range of the disease.

The results of damage appraisal surveys completed in pole-blighted stands were summarized in a paper to be submitted for publication. It shows that past and present damage has caused a serious reduction in the productivity of affected stands. To date nearly one-half of the white pine basal area and one-fifth of the total basal area of these stands is in diseased or recently killed pole blight trees. Mortality varies with age of infection; the old affected stands contain approximately five times as much mortality as recently affected stands. The annual loss from pole blight amounts to 174 cubic feet per acre over the 102,000 acres presently affected. Other effects of the disease have been a reduction in stocking and size class and a change in dominance and composition of the more important species.

Distribution and damage appraisal surveys of the dwarfmistletoes were started during 1956 on parts of the Colville and Nezperce (Idaho) National Forests. The surveys consisted of observations of dwarfmistletoe occurrence along roadside strips and more detailed study of its effects on sample plots established along lines run perpendicular to the roadside strips. A partial analysis of data from the roadside strip survey shows that 78 percent of the 550 miles covered on the Colville and 70 percent of the 370 miles covered on the Nezperce contained infected trees. In the Colville National Forest, western larch was infected on 86 percent of the miles on which it occurred, Douglas-fir on 76 percent, and lodgepole pine on 25 percent. Comparative values for the roadside strips on the Nezperce National Forest were: western larch 79 percent, Douglas-fir 62 percent, and lodgepole pine 53 percent. The results show that dwarfmistletoe has seriously reduced the productive capacity of many stands and in some cases has caused general stand deterioration. In local areas of heavy infection stand productivity is considerably below normal and there appears little prospect of ever developing fully productive stands as long as infected trees occupy the site.

Dwarfmistletoe was also found in ponderosa pine, grand fir, Engelmann spruce, and alpine fir during the course of the survey of the two forests but appears much less serious in these species except in a few localized areas.

## WHITE PINE BLISTER RUST AND MICROCLIMATE

During the year a meteorologist formerly with the U. S. Weather Bureau was added to the disease research staff to study the influence of microclimate on the spread and intensification of white pine blister rust. After completing a project analysis which defines the needs for basic research on this subject, he made an exploratory study of the variation in summer temperatures and humidity at the Priest River Experimental Forest in Idaho. It has yielded information on instrumentation, spacing of stations, personnel required to maintain a station network, and the range in variation of temperature and humidity over a small area.

A wooden radiation shield was designed to hold a maximum and a minimum thermometer. Sixty-two such shelters were constructed and placed on 45 different sites along the ridge to Gisborne Mountain and across the Benton Creek drainage under varying conditions of forest cover, slope, aspect, and elevation. At all 45 sites shelters were established at 2 feet above the ground to determine the distribution of temperature at the average level of ribes bushes. At 17 of the sites additional shelters were placed at 5 feet above the ground to determine the variation in temperature at the level of ribes bushes from that reported at the standard level for meteorological observations.

An instrument shelter was also designed which would hold a hygrothermograph. Ten such shelters were constructed and placed in the field at the 2-foot level to obtain a continuous record of temperature and humidity. An Assmann psychrometer was used to determine the distribution of temperature and humidity between stations, over predetermined routes or on selected sites on representative days.

The climatological data from this study on the Priest River Experimental Forest have been analyzed. Using relationships established between maximum temperatures on the various sites and those at the main meteorological station, the probabilities of various maximum temperatures being equaled or exceeded at any time and for any period of time were determined for each site. Considering the frequency and duration of occurrence of maximum temperatures necessary to prevent natural spread of the rust, it would appear from this preliminary analysis that on the Priest River Experimental Forest temperatures will inhibit spread and intensification of the rust only on those areas in the open on south-facing slopes below 4,000-foot elevation and then only during certain years.

## POLE BLIGHT OF WESTERN WHITE PINE

The Station's research effort in the Northern Region against western white pine pole blight this past year was largely concentrated in the three following activities:

Conclusions from root and soil studies to date.--All data obtained from root and soil studies were analyzed and a number of conclusions drawn. Root deterioration is pronounced both in diseased and in healthy portions of diseased stands and tends to increase with an intensification of pole blight. Rootlet density decreases and rootlet mortality increases as affected basal area increases, showing the close relationship that exists between the health of both the root system and the stand. Greater effective soil depths and available water storage capacities are associated with lower rootlet mortality, higher rootlet density, and less pole blight. This sequence of relationships suggests that edaphic factors influence, to an undetermined degree, the occurrence and severity of pole blight. Rootlet mortality in the upper 3 feet of soil is about two and one-half times greater in diseased stands on hardpan soils and about three times greater in diseased stands on rocky soils than in healthy stands on good soils. Stands situated on good soils possess three times as many live rootlets as stands growing on hardpan or rocky soils.

Moisture stress studies.--The study established in 1955 to determine the effects of an artificially imposed drought on 90-year-old western white pine trees was expanded during 1956. The soil in two additional areas containing white pine and several other commonly associated species (western redcedar, Douglas-fir, western larch, and lodgepole pine), was covered on June 1 with heavy plastic sheeting laid directly on the ground and fitted about the tree trunks. One plot will be covered continuously to exclude all or nearly all precipitation. The other plot will be uncovered each winter to allow for moisture replenishment and then recovered each spring. Soil moisture to a depth of 6 feet was reduced to a marked degree during the first summer of the test. Observations will be made periodically to determine if the several species included in this test react differently to moisture deficiency.

Four additional soil moisture plots were established during 1956 in the following types of white pine stands: old healthy, young healthy, healthy on rocky soil, and diseased on rocky soil. There are now a total of 16 moisture plots on which moisture sampling is periodically carried out. Soil moisture storage capacities, and rates of moisture depletion and replenishment are being determined in both healthy and diseased white pine stands. This information will help to clarify the soil moisture relationships to the pole blight disease.

An experiment was initiated to determine the effect of moisture stress on root development of seedlings. It tests five species (western white pine, western larch, Douglas-fir, grand fir, and western redcedar) planted and grown on three soil types (rocky, hardpan, and good soil). Two moisture treatments will be used. One will maintain sufficient moisture for optimum growth and the other will attempt to hold soil moisture near the wilting coefficient throughout the growing season. Wildings, approximately 1 foot in height, were planted in a randomized arrangement. Each combination of soil-moisture treatment is replicated twice. Moisture stress will not be imposed until the start of the 1958 growing season in order to allow each plant to establish and grow prior to testing.

Study of the root characteristics and abundance of eight tree species in white pine stands.--A 1-acre area in a pole-blighted stand was selected for a detailed study of root characteristics. Mortality of both rootlets and root tips of white pine was considerably less than of the other species studied except Engelmann spruce, which it exceeds slightly. Mortality in western hemlock and western larch rootlets and root tips was approximately twice as great as in white pine, and for grand fir, western redcedar, Douglas-fir, and lodgepole pine mortality ranged from two to three times as high as for white pine. However, for roots in the upper 1 foot of soil, grand fir, hemlock, spruce, and cedar had significantly higher root tip quotients (root tips per unit length of root), greater numbers of rootlets per unit length of root, and greater ratios of length of fine root (less than 1.0 mm. in diameter) to length of structural root (1.0 to 5.0 mm. in diameter) than did white pine, larch, lodgepole pine, and Douglas-fir. Of the latter four species, white pine appeared to be the least able to compete for moisture on the basis of root system alone.

## PONDEROSA PINE BLIGHT

In the Intermountain Region.--Serious damage by the Elytroderma blight of ponderosa pine occurs on only a small part of the total pine area. The marked localization of the disease strongly suggests that environment is a highly important factor in the epidemic behavior of the fungus. The affected areas are largely confined to the upper altitudinal limits of ponderosa pine where the species intergrades with other conifers such as alpine fir, lodgepole pine, larch, Engelmann spruce, and Douglas-fir.

Most all of the diseased stands are on ridge tops and south and west slopes. Boundaries of infection areas were mapped in 1950. Observations since then show that there has been no extension beyond these boundaries and suggest that aspect is also a factor of ecologic importance associated with the epidemic. Fogs and mists are fairly common in the fall over these areas.

The intensity of the blight epidemic reached a peak in 1950 and 1951. A marked decline in intensity of the disease occurred in 1952 and has continued since then at a slower rate. In 1955 most of the hysterothecia (fruiting bodies of the fungus) and the ascospores produced within them failed to mature, supposedly because of an abrupt weather change involving very high temperatures. A sparse crop of ascospores was produced in 1956. Present evidence, therefore, indicates that the epidemic may now have largely run its course.

Vigor of the host is associated with the fungus attack. Increment of the older pines has been markedly reduced for a number of years and the decline began quite some time prior to the start of the epidemic. Seedlings attacked by the fungus were found to be suppressed individuals of very slow growth rate and with a poorly developed root system. Within diseased areas vigorously growing seedlings with foliage of a healthy green color are present. This suggests genetic resistance, particularly since many of the large, old trees in the same stands show little or no evidence of the fungus.

The Elytroderma blight may be characterized as a disease largely confined to individual twigs, and usually not all of them. In some cases the extent of infection in a tree is limited to but a few twigs. Blighted twigs eventually die and it is in this manner. that some previously infected trees have now become free of the disease. A pruning experiment was started in 1955 at which time all diseased twigs were removed from 20 young ponderosa pines averaging 2.3 inches d.b.h. In 1956 no evidence of the fungus was found in any of these trees. Information gathered from observations and repeat color photographs plus the results of this experiment suggest that pruning diseased twigs may have a place in timber stand improvement.

For the past 3 years seven different fungicides have been tested each summer season on the pathogen. Results have been so inconclusive that it appears doubtful if any of the materials would be effective in controlling the blight.

Losses on permanent study plots were comparatively light in 1956 and occurred mainly in the smaller size classes. All dead trees showed a markedly reduced growth rate for the past 15 to 25 years or more. Within blighted stands losses from blowdown were much heavier than usual. Combined losses from windthrow, lightning, root rots, and bark beetles far exceeded the losses associated with *Elytroderma deformans*.

*In the Northern Region*.--*Elytroderma deformans* on ponderosa pine occurs in near epidemic proportions in the San Poil and Curlew Valleys in northeastern Washington. Some mortality has occurred and there is no evidence of a letup in infection. Limited branch infection occurs in ponderosa pine stands on the St. Joe and Kaniksu National Forests in northern Idaho.

## STEM RUSTS OF CONIFERS

In the Intermountain Region lodgepole pine is the common host of the blister rust fungus *Cronartium stalactiforme*. No thorough or systematic survey has been made to accurately appraise the prevalence of this disease and the damage caused by it, but during 1956 additional infection areas were discovered in the Region. One stand of lodgepole pine, in which a cursory examination was made last season, had an estimated 90 percent of the trees infected. Damage was heavy.

Pinyon blister rust (Cronartium occidentale) was found on Pinus monophylla in extreme northern Utah. All previous records of this fungus on pinyon pines in Utah are from the southern part of the state.

The Comandra blister rust (Cronartium comandrae) was found more widely distributed in lodgepole pine than previously recorded. Abnormally dry weather conditions were unfavorable generally this season for infection and intensification of the fungus on false toadflax, the alternate host plant. Some ponderosa pine plantations in southern Idaho, established in 1917 and 1918, are being largely destroyed by the pathogen. Tests of various herbicides for the control of toadflax, conducted during the past 2 years, have been unsuccessful to date.

The yellow witches' broom disease, caused by the rust fungus Melampsorella cerastii, has caused serious damage in recent years in a number of stands of subalpine fir. The pathogen not only kills trees, particularly in the younger age classes, but also reduces growth increment. Some subalpine fir stands have an estimated 80 to 90 percent of the trees infected.

## LODGEPOLE PINE NEEDLE CAST

The lodgepole pine needle cast fungus Hypodermella concolor continues its spread and intensification in the Intermountain Region. Although no systematic survey has yet been conducted, the pathogen is now known to be present on eight national forests. There is evidence that it may be considerably more widespread. The oldest infection areas known date back to about 1947.

Trees infected for successive seasons are reduced to needles of the current season, instead of normal retention for 6 to 8 years. Lower branches are sometimes killed. The growth increment of trees attacked for several successive seasons is greatly reduced and in one severely diseased stand that was examined a few trees have died. In this stand salvage cutting of the most severely affected individuals was conducted. Occasional trees show a high degree of resistance to the fungus.

In spring the symptoms induced by winter injury and by the needle disease are similar. This similarity sometimes results in confusion and a wrong diagnosis of the causal agent.

## OTHER DISEASES

The eastern white pine root disease at Sylvanite, Montana, reported in 1955 continues to cause limited mortality and has infected additional trees within the plantation. No mortality has occurred in other species. An inoculation study was initiated to determine if the Leptographium organism commonly isolated from infected roots is the cause. Naturally infected root sections were used in inoculations because the organism does not remain viable in culture. A faster growing Leptographium similar in growth rate to those isolated from pole blighted western white pine was also isolated from infected eastern white pine roots and is being used in the inoculation test.

No permanent damage to forest stands was observed as the result of the temperature drop in November 1955. Considerable foliage browning occurred on ponderosa pine in the vicinity of Spokane and along the Coeur d'Alene River valley. Other species suffered to a considerably less degree. No bud killing was recorded and by fall most traces of winter injury were gone. Several western redcedar stands scattered throughout the white pine type suffered abnormal bronzing of foliage and, in some instances, flagging. This was attributed to stand changes, brought about by cutting and to the dry period in late summer and fall.

Considerably less needle cast occurred in larch stands this season in comparison to past years. Several young stands were observed to drop their foliage earlier than normal apparently because of the dry conditions in late summer. No other species appeared to have been affected.

Extensive browning of foliage occurred in aspen stands on the Galatin (Montana) and Kaniksu (Idaho) National Forests. _Marssonia_ sp. was associated with most browning on the Gallatin while both this fungus and _Sclerotium bifrons_ teamed up to cause the damage on the Kaniksu.

The outbreak of ponderosa pine twig flagging, limited to one drainage on the Nezperce Forest (Idaho) in 1955, did not recur in 1956. Considerable flagging occurred in the overmature stands occupying the south-facing slopes and, while extensive, caused mortality in only a few trees. Isolations made late in 1955 revealed a frequently occurring fungus quite similar to _Diplodia pinea_. Isolations in 1956 from 1955-killed material showed various fungi to be present with _Diplodia_ occurring infrequently. No fruiting of _Diplodia_ or other fungi was observed. The primary cause, therefore, remains in doubt.

# FOREST INSECT RESEARCH

A program of research, insect surveys, and technical assistance on control projects provided full activity for the Station entomologists during 1956. Each of these phases of the program were active at the Missoula Forest Insect Laboratory, the Boise Research Center, and at the Ogden headquarters.

A review of accomplishments for the year shows significant advances. Considerable progress was made in analyzing the overall research program, making plans for termination of some projects and starting new studies. There was a significant increase in interest in the entomological program on the part of cooperators. During the year Station entomologists collaborated with a research committee of the Southern Idaho Forest Pest Action Council in evaluating the present research program in that area and in considering future needs.

Selected examples from each phase of the divisional program in the Intermountain Station area are presented.

## RESEARCH

During 1956 two new studies were started. As part of a review of research problems it was decided that expanded studies on spruce budworm and Douglas-fir beetle should not be delayed. Assignments for primary studies of spruce budworm were made at the Missoula Forest Insect Laboratory and for Douglas-fir beetle at the Boise Research Center. The review of other research projects continues and indications are that some studies can be terminated within a year.

### Tree Classification Based on Susceptibility to Pine Beetles

A series of seventeen 10-acre plots was established from 1950 to 1952 to test the effectiveness of the ponderosa pine risk rating system in measuring the relative susceptibility of ponderosa pine to attack by the western pine beetle. The system is highly effective in eastside stands of ponderosa pine in California and Oregon. The above plot establishment should reveal its effectiveness in the northern Rocky Mountain region. Biannual plot cruises reveal the accumulative tree mortality by risk classes. Since the plots were established the general level of pine beetles has been quite low. At the present rate of tree mortality from beetle attack it will take a longer period than originally anticipated to obtain sufficient data for sound analysis.

Through 1956 only 23 trees have been killed on the plots by western pine beetle. The following table shows the distribution of mortality within the risk classes. In spite of the small sample it is obvious that combined mortality in risk 3 and 4 trees accounts for the great majority of volume in killed trees.

Table 3.--Number and volume of ponderosa pines by risk classes killed by western pine beetle through 1956 (10 plots)

| Risk class | Number trees | Volume | Volume |
|---|---|---|---|
| | | Board feet | Percent |
| 1 | 0 | 0 | 0 |
| 2 | 4 | 3,950 | 18.7 |
| 3 | 5 | 3,050 | 14.4 |
| 4 | 14 | 14,120 | 66.9 |
| | 23 | 21,120 | 100.0 |

The study has been hampered by tree mortality resulting from a series of winds of hurricane force since 1950. Four windstorms have caused such serious uprooting of trees on study plots that one plot has had to be abandoned. It must be determined at once if other data such as post mortem classification of beetle-killed trees the year of death in the general area can be used to bolster the plot data.

One phase of the study being given special consideration is the possible interference from other bark beetles, notably the mountain pine beetle and the Black Hills beetle, upon tree selection by western pine beetle. Because all three are primary pests of mature ponderosa pine in Montana it will be necessary to determine whether the use of the ponderosa pine risk rating system will be rendered useless where attacks by mountain pine beetle predominate. Preliminary examination of data accumulated during 1956 indicates that the western pine beetle does not range east of the Continental Divide. West of the Divide its attacks are often accompanied by those of mountain pine beetle, the predominance of the latter increasing eastward toward the Divide. East of the Divide mortality was entirely due to attacks of the mountain pine and Black Hills beetles. There is increasing doubt that the designation of the latter two insects as separate species is valid. Morphologically they appear inseparable.

The present study may indicate that for all practical purposes the ponderosa pine risk rating system should only apply east of the Continental Divide unless subsequent studies reflect some tree selection tendencies of the mountain pine or Black Hills beetles.

## Selective Logging to Control Pine Beetles

Since 1950 periodic examinations have been made on areas in Montana that were logged according to a selective system under which high risk trees susceptible to attack by western pine beetle were removed. The system was developed in eastside stands of California and Oregon and is being practiced by operators in the northern Rocky Mountains without being tested in the area.

An additional study area was established in 1956 on the Piquett Creek Experimental Forest in Montana. The study is cooperative with Forest Management Research at the Missoula Research Center, the Montana State University School of Forestry, and the Bitterroot National Forest. The united effort will be a sanitation-salvage cutting of the high-risk trees plus a small amount of silviculturally undesirable trees. There will be three treatments, including the check on three different stand density classifications (light, medium, and heavy), replicated once. Accumulated post-treatment mortality data collected periodically will be the criterion for testing the validity of the risk rating system as the basis for selective cutting.

## Engelmann Spruce Beetle

Research to obtain biological information that would aid in control efforts was started with the epidemic outbreak of Engelmann spruce beetle in 1952 following severe blowdown.

Work continued until 1956 when final observations were made on this study. Considerable data were accumulated and are now being summarized for possible publication. It has been determined that species may have a 1-, 2-, or 3-year cycle in parts of the northern Rocky Mountains. Value of extreme cold as a control factor was demonstrated following severe low temperatures in 1955 when heavy mortality was observed in 1956.

No additional work was performed in 1956 on the use of trap trees as a control measure. The results of studies from 1953 to 1955 are being summarized. Results varied considerably between areas and apparent good control in some places was offset by indecisive results in others.

During 1956 reports were received that Engelmann spruce beetle was attacking western white pine where it was intermingled with spruce. Attacks were present but brood development was unsuccessful, ceasing before pupation. The concern over the possibility of the Engelmann spruce beetle spreading into white pine appears unwarranted.

### Douglas-fir Beetle

Limited studies have been conducted on phases of the Douglas-fir beetle problem during past years in the northern Rocky Mountains. Because of severe losses of timber that are being suffered from this beetle throughout the Douglas-fir type in the Intermountain Station area, a new study was started in 1956.

There is a pressing need for information on the epidemiology of the species. A study of populations and the factors affecting their increase and decrease is essential to the development of satisfactory methods to prevent or minimize losses. Basic to the entire study is the development of satisfactory methods of sampling populations. Work this past season therefore was concentrated on this phase of the over-all study.

Some facts were developed from the initial studies. Intensity of attack in standing trees averaged greater than records indicate for coastal Douglas-fir. A one-half square-foot bark section appeared to be a satisfactory sampling unit. There was a significant difference between the average number of attacks at the bottom, middle, and top of infested trees and samples from the middle of the infested length contained more attacks and showed less variability than others taken toward the upper and lower limits of the infested length.

The marked preference for beetles to attack windthrown trees rather than standing trees introduces the need for reliable methods of sampling populations in downed logs. Attacks are heaviest on shaded portions of this material, especially the north- or east-facing sides and bottom of the stem.

During 1956 the spring brood far outnumbered the summer brood. The fact that there are separate broods during the season makes it essential to develop reliable methods for use throughout the season.

An essential part of the over-all study will be evaluation of natural enemies including disease and other natural factors that exert control over beetle broods. During 1956 it was possible to start an inventory of parasites and predators. Adults that died during the spring were examined by disease specialists who, although not able to determine the cause of death, did recognize the possibility of disease organisms.

Analysis of data is incomplete. A progress report will be issued covering the results of the first season of work.

## Black Hills Beetle

Black Hills beetle is the major insect pest of ponderosa pine in southern Utah. Epidemics have come and gone at almost regular intervals on the Dixie National Forest and Bryce Canyon National Park. The present epidemic started in 1949. By direct control measures infestation has been controlled in many areas, but has developed in new areas. Control action undertaken during the present epidemic, demonstrated that there are serious gaps in our knowledge of the life history, habits, and epidemiology of the Black Hills beetle under conditions prevailing in southern Utah.

In order to clarify some of the biological relationships a limited study was started in 1954. The main efforts so far have been to determine the basic life history of the Black Hills beetle under epidemic conditions in this area. Using standing tree cages it has been possible to determine the periods and characteristics of beetle emergence. Brood sampling has provided fundamental information on population densities, attack patterns, and seasonal development, as well as some data on predators, parasites, associates, and host relationships. Additional work is needed in order to substantiate fully these findings. Efforts will be directed toward expansion of the ecological phase of this study, with particular emphasis on the predator, parasite, host relationship.

## Spruce Budworm

A study of spruce budworm was initiated during 1956. While facts on the life history and seasonal history are pretty well known through work in this country and Canada and a satisfactory direct control method is available, there is a need to determine ecological factors bearing on the rise and fall of populations.

Five permanent study plots were established on the Lolo National Forest in Montana. Plans call for analysis of factors operating to reduce populations at various stages of development throughout the season. Collections were made at three stages: (1) when early instar larvae were in tree buds, (2) when larvae were mature, and (3) in the pupal stage. All were dissected to determine extent of parasitism. Incomplete records to date indicate an aggregate parasitism of 50 percent. It is generally considered that an aggregate parasitism of 70 percent or higher forecasts a decreasing infestation.

Bole sections of Douglas-fir were collected last spring to determine relative populations in areas scheduled for aerial spraying. Emerging larvae were saved and representative samples were dissected. While two species of parasites are generally found, the dissection method followed was more suitable to check on the presence of one hymenopterous parasite, a species of *Glypta*. Of a total of 7,580 larvae from all areas, 31.9 percent were parasitized by *Glypta*.

During next season it will be possible to measure the factors throughout a complete life cycle in the established plots.

Budworm studies to date have been insufficient to relate actual populations to subsequent damage. Preliminary observations have been made on this phase in Idaho budworm outbreaks. A work plan devised for a study was prepared and limited field work performed during 1956.

## White Fir Needle Miner

The present epidemic of white fir needle miner has been serious in Bryce Canyon National Park and the adjoining Dixie National Forest in southern Utah for about 6 years. Attempts at control with chemicals prior to this period afforded no permanent relief.

In 1955 a cooperative study with the National Park Service was designed and initiated. The objective was two-fold: (1) to determine biological and ecological facts with particular emphasis on the seasonal development of the insect, and (2) to investigate possible methods of control, either direct or indirect, concentrating first on direct methods.

During 1956 it was determined that the needle miner has a 1-year life cycle with the larval stage present from early fall through the winter and until the middle of June. While the date of changes from one stage to another varied considerably, it appears to be tied to accumulative temperatures above 42° F. As more data are accumulated and refinements made in analysis it is hoped temperature relationship can be used in predicting development dates.

An evaluation of damage to the trees in relation to population was initiated. Sampling was done as the larvae reached maturity which coincided with maximum defoliation. Unfortunately, in spite of attempts to select plots at various population levels, developments during the season revealed heavy defoliation at all points. The ratio of needles mined per miner were similar in the different areas. Needle miner populations did vary some by crown position and size of tree. Seedlings were less heavily infested than poles or mature trees.

Tests of two insecticides, DDT and Malathion, were conducted following procedures used in 1955. Results this year using hand-operated equipment showed that larval mortality in excess of 95 percent can be expected when the needles are sprayed with an oil solution containing Malathion at the rate of 1 pound per gallon. In this spraying, attempts were made to apply the solution at the rate of 1 gallon per acre. The rate was judged by comparison with standard dyed cards developed for use in aerial spraying. The spray appeared equally effective applied any time after the larvae became active in the spring (one-third to one-half grown larvae) until pupation occurred.

It was noted that many trees severely damaged by needle miner were attractive to and succumbed to attacks by the fir engraver, *Scolytus ventralis.*

## Spruce Mealybug

Spruce mealybug (*Puto* sp.) is apparently unknown in the United States other than in southern Utah. Here its host is Engelmann spruce of all ages from seedlings to mature trees. The species has been found on about 60,000 acres and its feeding has resulted in considerable killing of limbs, deformity of trees, and limited tree mortality. Lacking observation during the earlier life of the infestation, the rate of deterioration of the infested stand has not been determined.

The infestation is located in extensive stands of Engelmann spruce and the need is present to determine the potential for damage of the pest. To do so, determination of the life history and habits of the species as well as an understanding of possible natural control factors are essential.

Limited studies thus far have determined that at least three seasons are required to complete the life cycle. The species overwinters in two forms, the adult female and immature stages. Hibernation occurs at bases of trees and in duff with migration of young from tops of trees to base and back again the following season. Winged males have been found only occasionally.

Feeding by both adult females and the young takes place on foliage and terminal twigs. Damage to seedlings could seriously interfere with regeneration in the area.

### Improvement of Insect Survey Methods

Improvement of both aerial and ground insect surveys is essential. Developments by aerial survey research units at Beltsville, Maryland and the Pacific Northwest Forest and Range Experiment Station will be of assistance to our research program. Efforts are necessary to adapt developments elsewhere to local conditions and to develop new methods that are suitable for special conditions within our areas.

For the first time during the present spruce budworm outbreak in Montana, growth conditions introduced a factor that hindered the aerial surveys. Rapid growth of terminals masked the extent of feeding by larvae so it was impossible to segregate light, medium, and heavy damage. Lower flying patterns were followed coupled with more intensive ground sampling which improved results but did not solve the difficulty. If such conditions occur more commonly, methods must be developed to overcome the handicap.

One of the great needs is improvement in the appraisal of infestations through the application of research developments. In 1955 it appeared that control operations might be warranted against an outbreak of Douglas-fir tussock moth in northeastern Washington and northern Idaho. A research entomologist undertook dissection of pupae and examination of egg masses to see if the trend of the population could be determined. As a result it was decided that parasitism and other natural control factors had reduced the population to a point that little damage would result in 1956. Plans for control were held in abeyance. Developments during the following summer substantiated the prediction and the outbreak decreased to a very low level.

## INSECT SURVEYS

The annual insect survey program in the Intermountain Station territory was carried out as planned. The aerial phase of the survey was expanded with approximately 440 hours of observational flying over the forests of Regions 1 and 4. While complete coverage was not attained the most important forested areas were surveyed. It is believed that there are no serious insect outbreaks developing unnoticed.

Ground surveys were intensified. Considerable help was received from cooperators in National Forest Administration, the National Park Service, lumber industries, and from private individuals.

Appraisal surveys were made where situations appeared serious enough to warrant consideration for possible control measures. Reports were furnished to land managing agencies informing them of the status of insect problems on their lands.

A brief summary of the more significant insect situations follows. The spruce budworm was again the outstanding forest pest in Montana and Idaho. There are at present about 3.5 million acres of infestation in the fir stands of Montana and northern Idaho and approximately 650,000 acres in southern Idaho.

The Engelmann spruce beetle epidemic that appeared during 1952 in western Montana and northern Idaho appears to have returned to endemic levels in 1956 with the exception of a few scattered centers. Additional blowdown in the spruce timber type during the past year could result in a population increase unless salvaged. The spruce beetle epidemic in Wyoming on the Bridger National Forest continues at a high level although the past year shows little expansion areawise.

The mountain pine beetle is relatively quiet in the northern Rocky Mountains but shows disturbing tendencies toward increasing levels in forests in Utah and Wyoming. The outbreak on the Ashley and Wasatch Forests in Utah continues at a high level with an estimated loss for the year of 100,000 trees. The Black Hills beetle has been at epidemic levels in southern Utah since 1949. Control efforts since 1950 have reduced populations in treated areas but new outbreaks develop each year in other sections of the forests. The southwestern pine beetle on the Nevada National Forest recreational areas is being reduced each year by maintenance control throughout the season.

Other outbreaks recorded involve a fir needle miner and a spruce mealybug in southern Utah, four species of defoliators on areas of western larch in western Montana, northern Idaho, and eastern Washington estimated at 100,000 acres, black-headed budworm in Idaho and Montana, and a sawfly on lodgepole pine in Yellowstone National Park.

An unusual outbreak was recorded in Douglas-fir stands in the Craters of the Moon National Monument near Arco, Idaho. There are no previous records in this area of significant defoliation of Douglas-fir by sawflies. Dr. H. H. Ross of the State National History Survey Division at Urbana, Illinois determined the species as Neodiprion, abietis complex. Snowfalls forced a postponement of surveys until spring.

# TECHNICAL ASSISTANCE

Station entomologists have responsibility for furnishing technical assistance to control projects conducted by land-managing agencies. 1956 was a busy season.

The Station's assistance consists of participation in pre-control planning, advice on methods, materials, and timing of the spray application, assistance in training of operational personnel, inspection during operations, and checking of the results.

Aerial spraying of 1,360,000 acres of spruce budworm infestation in Montana and Idaho was the largest undertaking in 1956. Preparation for the projects, critical timing of aerial phases, and the biological checking required makes aerial spraying one of our most exacting technical assistance activities.

Technical assistance was furnished on Engelmann spruce beetle projects. The outbreak in Montana that has been the subject of control by logging and trap logs since 1952 has decreased greatly. At the present time there are a few isolated spots that still present epidemic tendencies. The Engelmann spruce beetle outbreak that developed on the Bridger National Forest in Wyoming in 1955 continues to pose a serious threat. Logging plus some trap log activity is being used to reduce the infestation. While the outbreak did not expand greatly in area in 1956 it did build up in intensity within the zone of infestation.

A combination of direct chemical control plus logging has been used in southern Utah on the Dixie National Forest and Bryce Canyon National Park for the past 6 years. Drought conditions in the area over the past 7 years no doubt have contributed to weakened tree conditions and the severity of the beetle outbreak. Control in one area produces significant reductions but populations develop to outbreak proportions all too frequently in new areas.

The southwestern pine beetle has been causing severe losses on Charleston Mountain in Nevada for several years. This area is one of high use by the public for recreational purposes. A program of all season survey and chemical treatment has been practiced. Constant attention to treatment of newly infested trees appears to be the most successful method yet tried to reduce losses from this species of insects that has several broods during the season.

On the Teton National Forest in Wyoming a chemical control project was necessary in 1956 to reduce an outbreak of mountain pine beetle in lodgepole pine. The outbreak was confined to an area of about 2,300 acres but groups of infested trees indicated a rapidly increasing population of beetles.

# FOREST FIRE RESEARCH

Lightning fires, logging slash, fire-danger rating, fire equipment, fire prevention, and fire behavior were the major fields of activity of the Division of Forest Fire Research during 1956.

Following the pattern of 1955, parts of the West experienced drought, severe winds, outbreaks of lightning fires, and periods of critically high fire danger. In some cases these conditions resulted in mass fire. Unfortunately, in the Intermountain Station territory and elsewhere in the West there was tragic loss of life during some of the fire-fighting operations. These events again point to the need for continued progress in fire control. The key to progress in fire control is scientific research.

## COOPERATION IN FOREST FIRE RESEARCH

For several years the Division of Forest Fire Research has reported on the assistance given by cooperating agencies. During 1956 cooperative activities reached a new high, permitting more aggressive attack on several important fire research projects. Much of this activity by cooperators serves as a catalyst to get the work under way. However, the efforts of cooperators do not insure continuation of the projects and maintenance of proper levels of work, nor do they solve all of the problems of research financing and development of needed scientific facilities.

Activities of cooperators in forest fire research during 1956 were as follows:

Munitalp Foundation.--Dr. Vincent J. Schaefer, Director of Research for the Munitalp Foundation, continued as technical leader of Project Skyfire and assisted in studies of fire behavior and general forest fire meteorology problems. Dr. Paul J. MacCready directed the experimental meteorology phase of Project Skyfire and assisted in all field operations in cloud seeding. Donald M. Fuquay was on full-time duty at the Forest Fire Laboratory serving as staff meteorologist and assisting in all phases of Project Skyfire. In addition to these technical personnel, Munitalp provided cash and much scientific equipment for the research program.

Advisory Committee on Weather Control.--During 1956 the Forest Service entered into a formal cooperative agreement with the President's Advisory Committee on Weather Control. The agreement provides for cooperative analysis and evaluation of cloud seeding as a possible means of lightning prevention. To facilitate this activity, the Advisory Committee assigned Robert B. Smith, research meteorologist, and H. J. Wells, chief aerologist, to the Forest Fire Laboratory. In addition, the Committee provided cash, scientific equipment, and general technical service for the evaluation of the lightning-fire prevention phases of Project Skyfire.

U. S. Weather Bureau.--DeVer Colson, research meteorologist of the Weather Bureau's Washington office, again spent the field season with the Project Skyfire group assisting in lightning storm analysis. W. R. Krumm, fire-weather forecaster at Missoula, gave general assistance on nearly all phases of the fire research program. Fire-weather forecasters at Missoula, Montana and Boise, Idaho and the Weather Bureau offices at Salt Lake City, Utah and at Phoenix and Flagstaff, Arizona assisted in the research program. Special weather forecasts and analyses were prepared by the Severe Local Storm Forecasting Center at Kansas City, Missouri and the Fire-Weather Forecasting Center at Missoula. The Weather Bureau provided scientific equipment, including radar which was built into the Project Skyfire mobile radar unit.

Montana State University.--Robert Steele, of the School of Forestry faculty, worked in cooperation with the Forest Fire Laboratory on the Project Skyfire, logging slash, and fire prevention programs. The staff of the Forest Fire Laboratory cooperated with Steele in the establishment of a new course in forest meteorology at the University.

University of Idaho.--Cooperative logging slash research continued with the Forest, Range, and Wildlife Experiment Station of the University of Idaho. David Olson of the University staff assisted in studies of logging slash volume and flammability and hazard reduction.

University of Washington.--The mobile atmospheric research laboratory built by the University of Washington in cooperation with the Munitalp Foundation, was again an important factor in the gathering of field data for several phases of the fire research program. Dr. Konrad Buettner, of the school of Meteorology and Climatology, assisted in flammability studies.

National Park Service.--All of the national parks in the Station's territory cooperate in the fire-danger-rating program. National Park Service personnel at Dinosaur National Monument and Zion National Park, Utah assisted in fuel moisture studies. Yellowstone National Park operated one of the Project Skyfire cloud and lightning survey stations.

Bureau of Land Management.--In southern Idaho the Bureau of Land Management assisted in fuel moisture and fire-danger-rating research at three stations. Work is continuing on fire-danger-rating research for the Bureau of Land Management areas in Alaska. During 1956 fire-danger-rating data were obtained at 12 Bureau of Land Management stations in the Alaskan interior.

Meteorology Research, Inc.--Under contractual arrangements made by the Advisory Committee on Weather Control, Meteorology Research, Inc. assisted in the Project Skyfire field program in Arizona and in the northern Rockies. This firm provided six research technicians, an airplane, and much scientific equipment.

California State Division of Forestry.--At the end of the year arrangements were made with the California State Division of Forestry for cooperation on Project Skyfire. Shop and laboratory facilities at Davis, California will be used to expedite the program of developing, testing, and calibrating cloud-seeding generators needed in lightning fire research.

National Forest Administration.--During 1956, Regions 1, 3, 4, and 6 of the Forest Service assisted in many phases of the fire research program. National forest personnel operated 21 Project Skyfire cloud and lightning survey stations, gathered and assisted in compiling fire-danger-rating data in seven states, and assisted in logging slash research on three national forests. The fire-weather equipment development project and studies of field operations of fire-danger rating are joint programs between the Forest Fire Laboratory and National Forest Administration.

## FOREST FIRE LABORATORY

During 1956 further improvements were made in the scientific facilities at the Forest Fire Laboratory at Missoula. A small laboratory room was partially equipped for electronic research in connection with the Project Skyfire research program. At the end of the year plans were completed for equipping a basement room as a laboratory needed in the development and testing of meteorological equipment and cloud-seeding generators. This laboratory room will include a small wind tunnel, work benches, and equipment for developing, testing, and calibrating instruments.

The main field arm of the forest fire laboratory is at the Priest River Experimental Forest in northern Idaho. The facilities at Priest River are used in fire-danger-rating research, fire-weather equipment development and testing, logging slash flammability experiments, and Project Skyfire.

Development of adequate scientific facilities is one of the major problems facing the Division of Fire Research. Many of the things needed for progress in forest fire control cannot be developed without adequate laboratory facilities and scientific equipment. During 1956 plans were prepared for a forest fire laboratory building proposed for construction at the U. S. Forest Service Aerial Fire Depot at the Missoula airport.

## PROJECT SKYFIRE

Project Skyfire continued active field and laboratory research aimed at (1) gaining basic information on lightning fires and storms, and (2) testing the possibilities of preventing or reducing the severity of lightning fires through cloud modification. Project Skyfire involves lightning fire research throughout the western United States. During 1956 the main field experiments were conducted in Arizona and in the northern Rockies.

### Cloud and Lightning Survey

The cloud and lightning survey was continued from a network of 22 forest fire lookout stations in Oregon, Washington, Idaho, Montana, and Wyoming. A network of 4 stations was operated in Arizona from mid-May to mid-July. Each day during the fire season the observers at these stations recorded the development, movement, and action of cumulus clouds, middle-level clouds, and upper-level clouds. When lightning occurred they recorded data on location and number of strikes, and prepared a map of the storm path in their area. Reports and maps prepared at each lookout station were forwarded to the Forest Fire Laboratory for compilation of regional summaries. In addition, a radio network was used for daily collection of cloud and lightning data from all Skyfire stations. These procedures enabled the Project Skyfire staff to be kept up to date on the cloud and lightning situation and to make daily evaluations of cloud seeding potentials.

A special training school for Project Skyfire lookout observers was held at the Priest River Experimental Forest. Following the school each Skyfire lookout station was visited to give additional on-the-ground instruction to the observers. This effort resulted in a smooth-functioning cloud and lightning survey network which gathered valuable data for lightning-fire research.

The techniques developed in the cloud and lightning survey should prove useful to fire-control organizations throughout the western United States. Proper information on clouds and lightning is useful in evaluation of fire danger, fire-control planning, dispatching, and in determining fire-suppression strategy and tactics. Furthermore, cloud and lightning surveys are essential in the conduct of cloud-seeding operations. If cloud seeding proves successful as a means of lightning-fire suppression, cloud and lightning surveys may become a standard part of the over-all fire-control operations.

### Lightning Analysis

Work was continued on lightning storm analyses in the northern Rockies. Data collected at Skyfire lookout stations, supplemented by atmospheric data collected by the U. S. Weather Bureau, are analyzed for each lightning storm. During 1956, regional lightning-storm maps were prepared for each storm occurring during the fire season. These studies again show an intense lightning-fire zone extending from the area around the Snake River Canyon on the Oregon-Idaho boundary northeastward to the Bitterroot and Lolo National Forests in Montana and Idaho.

Research on lightning fires is revealing several critical zones throughout the western United States. A summary of lightning-fire occurrence is shown in table 4.

Table 4.--Summary of lightning-fire occurrence in the western United States

| | Total lightning fires 1940-1955 | Average annual occurrence of lightning fires | Average annual lightning fires per million acres protected | Proportion of total fires that are lightning-caused |
|---|---|---|---|---|
| | Number | Number | Number | Percent |
| Arizona | 20,029 | 1,252 | 64.84 | 84 |
| Colorado | 2,348 | 147 | 5.83 | 35 |
| Idaho | 15,997 | 1,000 | 34.32 | 69 |
| Montana | 9,720 | 608 | 22.43 | 71 |
| Nevada | 464 | 29 | 2.09 | 34 |
| New Mexico | 7,736 | 483 | 31.52 | 79 |
| So. Dakota | 1,715 | 107 | 33.57 | 62 |
| Utah | 1,309 | 82 | 3.82 | 35 |
| Wyoming | 1,569 | 98 | 7.55 | 62 |
| California | 14,981 | 936 | 22.20 | 26 |
| Oregon | 15,503 | 969 | 31.46 | 52 |
| Washington | 8,092 | 506 | 20.19 | 28 |
| Western States | 99,463 | 6,217 | 23.44 | 48 |

## Cloud Seeding--Arizona

Northern Arizona experiences one of the most critical lightning fire loads in the United States. The Coconino National Forest has averaged 343 lightning fires a year during the 16-year period, 1940-1955. During the mid-May to mid-July period, a dry, isolated type of lightning storm frequently occurs in this area, setting many fires and causing great damage. These local air-mass-type storms can be better understood than more complex storms. Their simpler nature makes them good targets for cloud-seeding research because of a better opportunity to observe and analyze the results.

For all of these reasons the Coconino National Forest was selected as the site of a Project Skyfire field operation during the spring and early summer of 1956. Through the cooperation of the Munitalp Foundation, the President's Advisory Committee on Weather Control, the U. S. Weather Bureau, Meteorology Research Inc., the Rocky Mountain Forest and Range Experiment Station, and Forest Service Region 3, a task force moved to the Coconino National Forest in mid-May to carry on field experiments. Headquarters for the operation were established at the Fort Valley Experimental Forest near Flagstaff, Arizona. The nearby San Francisco Peaks area appeared to be an excellent site to observe cloud growth and action and to test cloud-seeding techniques.

The main objectives of the Arizona operation were: (1) to study local air-mass-type lightning storms, (2) to test cloud-seeding techniques and equipment, and (3) to evaluate possible effects of cloud seeding on lightning-storm development and action. To carry out these objectives the operation involved the use of two aircraft, a mobile radar unit, five ground-based cloud-seeding generators, four cloud and lightning-survey stations at fire lookouts, a radio network, and a wide variety of scientific equipment. The 13-man research group included foresters, meteorologists, aircraft pilots, and field assistants.

A principal result of the Arizona experiment was the development of suitable equipment and techniques for experimental seeding of potential lightning storms over mountainous country. Light aircraft equipped with a high-output silver iodide generator proved very satisfactory for this type of experimental cloud seeding. The aircraft can be deployed underneath the target cloud with the silver iodide crystals being carried into the cloud by convective action. Light aircraft also proved successful in measuring atmospheric factors, taking samples of atmospheric nuclei, and making observations of seeding effects.

The results of 12 cloud-seeding missions show that local air-mass-type clouds can be modified. The most evident modifications include: (1) appearance of virga (precipitation from cloud which does not reach ground), (2) deterioration of cloud base, and (3) glaciation in cloud tops. Cloud deterioration was frequently observed. These factors could lead to a reduction in the severity of lightning and a consequent reduction in lightning-caused forest fires.

### Cloud Seeding--Northern Rockies

Immediately following the Arizona experiment, the Project Skyfire research group moved to Missoula to carry on similar experiments in the northern Rockies. A test area was selected in rough, mountainous country on the Lolo National Forest. The test area is a high-lightning-occurrence zone within easy reach of the supporting research facilities of the Forest Fire Laboratory, the U. S. Forest Service Aerial Fire Depot, the Weather Bureau Fire-Weather Forecasting Center, and the Missoula County Airport. The test area is surrounded, also, by the Project Skyfire cloud and lightning-survey network.

The cloud-seeding experiments in the Lolo National Forest followed the pattern set in Arizona and capitalized on that experience. From late July to mid-September both aircraft and ground-based generators were employed in cloud-seeding tests of growing cumulus clouds. More ground generators were used than in the Arizona tests because of the need to gain more knowledge of this type of cloud seeding for lightning-prevention purposes. Aircraft were used extensively with both aerial and ground seeding to make atmospheric measurements and to observe seeding effects.

The results of the experiment in the northern Rockies again show that growing cumulus clouds can be modified. Appearance of virga, deterioration of cloud base, and glaciation in cloud tops were observed following seeding of growing cumulus clouds. Modification following seeding is not always readily observable. The results of aircraft seeding on growing cumulus clouds are easier to analyze than are the results of seeding from ground generators. The effects of seeding from a network of ground generators may produce more widespread modification, but the results are more difficult to analyze and require detailed observations over a larger area.

The 1956 field program involved pioneer development and testing of special cloud-seeding techniques and equipment. While much progress was made, the field experience showed the need for increased research on cloud-seeding techniques for lightning prevention and on the development of many items of equipment. Analysis techniques likewise require much attention.

As a result of the 1956 experiences, plans are now under way for cloud-seeding research during the 1957 fire season. Extensive tests are planned in the critical lightning-fire belt along the summit of the Bitterroot Range on the Lolo National Forest in Idaho and Montana. These experiments will be aimed at gaining quantitative data on the possible degree of lightning suppression from cloud seeding.

## Atmospheric Nuclei Studies

Evaluation of natural cloud action and the effects of cloud seeding requires measurement of the presence of atmospheric nuclei. With an understanding of the presence of atmospheric nuclei it is possible to find out how much additional nuclei are being produced in a given area by cloud-seeding generators. Tracing the plume from the cloud-seeding generators is an essential phase of the over-all Project Skyfire experimental program.

During 1956 techniques and equipment were developed for the measurement of natural-freezing nuclei and nuclei produced by cloud-seeding generators. Aircraft were used to trace silver iodide plumes. A cold box mounted in aircraft is used to study air samples gathered along the flight path. Silver iodide crystals can be seen in the cold box and the concentrations determined. The present stage of knowledge of seeding requirements for lightning suppression indicates that the desired objective is to produce 10,000 silver iodide particles per cubic meter at the bases of convective clouds.

## Generator Development and Calibration

The 1956 field program showed the need for a special type of ground-based generator for cloud-seeding operations aimed at lightning suppression. This generator needs to be rugged and easily serviced for field use, economical in operation, safe from a fire standpoint in flammable forests, and it must produce a high output of silver iodide crystals at relatively warm temperatures. During the fall and early winter of 1956 work was started at the Forest Fire Laboratory in the development, calibration, and testing of such a generator.

Generator development and calibration requires special equipment and techniques. The first step in this program was to calibrate existing generators and experiment with methods for increasing their output. A mobile wind tunnel was built for the collection of samples for generator plumes. Techniques were developed for the examination of samples in cold chambers. By the end of the year encouraging progress had been made in the generator-development and calibration program. As a result, it is expected that a high-output cloud-seeding generator will be ready for manufacture in considerable quantity early in 1957.

## Radar

During 1956 a completely mobile radar unit was designed, built, and used by Project Skyfire. The radar unit came into being as a result of a cooperative effort by the Munitalp Foundation, the U. S. Weather Bureau, the Advisory Committee on Weather Control, and the Forest Service. Surplus military radar equipment was modified, mounted in a specially built 14-foot trailer, and provided with power from two gasoline engine generators.

The mobile radar unit provides a field nerve center for the Project Skyfire cloud-seeding program. On the main radar scope lightning storms can be detected, tracked, and analyzed. Precipitation echoes seen on the radar scope aid in the evaluation of cloud-seeding results. A time-lapse camera mounted in front of a second radar scope and controlled through an electronic circuit provides a permanent record on film of the life cycle of each storm or cloud sequence.

The Project Skyfire mobile radar unit proved to be a rugged outfit. Preliminary construction was accomplished in the instrument shop of the U. S. Weather Bureau in Washington, D. C. From there the unit was towed to Missoula where construction and testing were completed in the Forest Service shops. Next, the radar unit was moved to Flagstaff for service on the Arizona cloud-seeding experiment. From Arizona the unit was towed to a high peak in the Lolo National Forest in Montana where it aided in the northern Rockies experiment until the end of the 1956 fire season. Through all of this rugged service the radar unit proved relatively trouble-free and satisfactorily performed the job for which it was designed.

The Project Skyfire mobile radar unit is a pioneer effort to employ modern electronic science in attacking the lightning-fire problem. This unit was quickly assembled from available surplus equipment and is by no means in an advanced stage of development. However, even the present rather elementary equipment and the limited experience with it show that radar and other electronic systems can be of great value to lightning-fire research and to fire-control operations. Further development of radar can lead to new and improved methods for detecting, tracking, and analyzing lightning storms, rapid plotting of fire zones, controlling aerial patrols, dispatching fire fighters, and planning fire-suppression operations.

## Reporting Project Skyfire Results

At the national meeting of the American Meteorological Society held in New York City January 23-26, 1956 a special session was devoted to Project Skyfire. A panel of five papers was presented as follows:

"Atmospheric Studies from a Moving Weather Observatory", by Dr. Vincent J. Schaefer.

"The Skyfire Cloud Survey", by J. S. Barrows.

"Cloud Measurement Techniques", by Dr. Paul B. MacCready, Jr.

"A Mobile Atmospheric Research Laboratory", by Donald M. Fuquay.

"Thunderstorm Analysis in the Northern Rocky Mountains", by DeVer Colson.

# FIRE-DANGER RATING

The fire-danger-rating project is made up of three fields of endeavor--developing burning-index ratings and fire-danger-rating systems, training observers and fire fighters, and developing fire-danger-rating equipment.

## Developing Fire-Danger-Rating Systems

The Model 8 Burning-Index Meter.--The model 8 meter has now served the Intermountain area for 2 years. This year the meter was used by all fire-protection agencies in Nevada, Utah, Idaho, western Wyoming, Montana, portions of Washington and South Dakota, interior Alaska, and parts of British Columbia and Alberta. The meter is well-received and confidence is held in the ratings rendered by it.

Fuel stick manufacturing program.--A working arrangement with the Forest Service warehouse at Spokane, Washington for fuel stick production has been in effect for several years. The warehouse has production and distribution responsibility; the Forest Fire Laboratory has technical responsibility for the quality of the product. Through experimental work at the warehouse, the quality has been raised so that the sticks are actually made to closer tolerances than specified. At the same time the price of the product has not been increased.

Fuel stick quality control.--Each summer a random sample of fuel-moisture sticks is exposed and measured at Priest River Experimental Forest in northern Idaho. This year's testing, as in the past, showed the product to be uniformly accurate and consistent.

Fuel-moisture stick leaching study.--In the wetter coastal climates fuel-moisture sticks tend to lose up to 2 percent (3 percent under extreme conditions) of their oven-dry weight when exposed all summer under a screen. In the drier inland climates the loss is between 1/2 and 1½ percent. It was thought that a series of hot baths might leach out soluble salts and resin before the sticks were trimmed to their 100-gram basic weight, thus minimizing the difference in loss factors during the field season between wet areas and dry areas.

Eighteen sets of sticks were treated. Three sets were soaked in water at 90° F. for 1 day, three for 2 days, and three for 3 days, and similarly in 150° F. water. Between 1 and 2 percent of the oven-dry weights were lost in this preleaching procedure.

After being exposed all summer at Priest River Experimental Forest the preleached sticks had lost about the same percent of oven-dry weight as had those used in the quality-control test. The general conclusion is that the bulk of the loss during the summer is due to erosion and not to leaching. At present no means of counteracting this loss is contemplated other than protection under screens.

Type of screening material study.--Three sets of sticks were placed under each of four different types of screens: galvanized iron, aluminum, copper, and an experimental small iron wire screen. The data have not been worked up yet. The raw data indicate that sticks under the aluminum screen may be slightly drier than sticks under the other types. Screens apparently reduce weight loss of fuel-moisture sticks.

Fuel-moisture experiment.--The Bureau of Land Management, National Park Service, and other protection agencies guard many thousands of acres of cheatgrass and sagebrush lands. In order to find the best possible combination of fuel factors to incorporate into the burning-index meter, a study was set up this past summer to observe the reaction to the weather of 1/2-inch fuel-moisture sticks and basswood "Appalachian" slats, both under a screen and in the open. Comparisons were made at two Bureau of Land Management lookouts and at Boise in southern Idaho, two at Dinosaur National Monument, one at Zion National Park in Utah, and one at Priest River Experimental Forest. The data are to be processed in the spring of 1957 and recommendations made to the cooperating agencies.

Alaska study.--The Bureau of Land Management lands in interior Alaska have had no system of fire-danger rating prior to 1956. Seven standard fire-danger stations were installed and measurements were made all during the summer. The resultant burning indexes were compared to actual fire conditions. In general, the reported high rate-of-spread of fires in the fuels of interior Alaska indicates either that the meter rates conditions too low or the rate-of-spread factor exceeds that for any fuels of the Intermountain area. More study is needed to correlate burning indexes with the fire problems of interior Alaska.

Large log study.--Daily measurement was continued of the moisture content of large logs exposed in a clear-cut area and also in a fully timbered area at Priest River Experimental Forest. It is hoped that one more summer's daily measurements will yield significant data for more accurately integrating the reaction of heavy fuels and soils with fluctuations of the weather, both short- and long-term. There have now been three summers of daily measurements, and 10-day measurements have been taken since 1942.

## Training

An integral part of forest-fire research is the dissemination of research findings to the technicians of forest protection organizations.

Visits to forests.--A general policy, decided upon in 1955 at a joint meeting of the Forest Fire Laboratory, forest protection agencies, and the U. S. Weather Bureau, is that each forest protection unit will be visited annually either by a Forest Fire Laboratory technician or by a member of the fire-weather forecaster's staff. He, with the forest-fire staffman of the protection unit, inspects intensively at least one fire-danger station and gives all the training that time permits. The fire staffman then attends to bringing the standards of all the fire-danger stations on the protection unit up to the level of the one inspected. This procedure has permitted a very few men to give annual assistance to nearly three dozen national forests and several other public and private forest protective agencies.

Training materials.--Many training aids are now in the hands of fire people. Such aids are the fire-danger station handbook, burning-index prediction methods, projection of burning index in time, aspect and slope, and rate-of-spread tables. Members of the Forest Fire Laboratory endeavor during visits and inspections to acquaint the personnel with these aids, make them easier to understand, and urge their wider use.

Fire behavior training.--The best means for getting fire behavior information to the fire fighter is through a trainer-training program. Fire research personnel cooperate with regional and forest staff men in presenting instruction to key men who in turn carry out training programs on the various protection units. Factors of fire behavior and fire weather that affect blow-up conditions and personal safety are stressed. During 1955 fire-research personnel participated in fire-training programs of the Forest Service in Regions 1 and 4, of the National Park Service, and the Bureau of Indian Affairs. Special emphasis was given to fire training in Utah in cooperation with the Utah State Forester's office.

## Fire Equipment Research

The fire-danger-rating equipment designed last year was thoroughly tested this summer at the Priest River Experimental Forest and at other field stations.

Wind counter.--A battery-powered totalizing counter that has a minimum-battery-drain feature has been tested; plans and specifications are ready for final approval before the instrument is put into production. The counter will work with any contact-type anemometer.

Fan psychrometer.--Plans and specifications have been completed for a simple battery-powered, small electric motor-driven-fan unit to replace the hand-crank unit on the Forest Service fan psychrometer assembly. A complete psychrometer assembly can also be built locally if the fan unit and a sling psychrometer are available. The Spokane warehouse has built 100 units to satisfy immediate demands within Forest Service Regions 1 and 4.

Aluminum rain gage.--Plans and specifications are now ready for a seamless aluminum rain gage that has about the same dimensions as the present galvanized sheet iron gage. Plans and specifications have been completed, also, for a fiber (Lamicoid) rain gage measuring stick to replace the present stick. The fiber gage will not split; it can be washed; and water will not "creep" on it. The U. S. Weather Bureau has adopted the material for its standard measuring stick.

Fuel-moisture screen.--Plans and specifications have been completed for a simplified method of constructing the standard fuel-moisture screen. Screen replacement will be a great deal easier with this new design. A much smaller screen, which includes brackets for the sticks at the proper height, was tested. Sticks under this screen had about the same moisture content as sticks under the standard screen. A simplified design will be field-tested in 1957.

Portable fire-danger station.--All testing of a portable fire-danger station has been completed except for dropping by parachute from a plane. The portable station was used extensively on two prescribed burn areas during 1956. The instrument panel is now being altered to permit easier reading. The portable fire-danger station will be available for general use during the fire season of 1957.

Knock-down aluminum instrument shelter.--The new shelter is a 24-inch cube when assembled, and stands on 48-inch legs. When packed ready for carrying it forms a package only 5 inches thick. The legs fit snugly into a bracing member and can be carried as a single piece. The Missoula office of the U. S. Weather Bureau is now testing the shelter for low-temperature accuracy. Upon completion of these tests and modification of the leg assembly to eliminate vibration during heavy winds, the shelter will be ready for preparation of final plans and specifications.

## LOGGING SLASH RESEARCH

### Logging Slash Flammability

During 1956 field and analysis work was virtually completed on studies of variations in flammability according to species, age, and amount of logging slash. The only field work still to be completed is experimental burning of plots containing 5-year-old slash. These tests must await 3 more years of slash aging.

Logging slash reaches its highest state of flammability during the first year following cutting. Weather factors, of course, have a strong influence. During the fire season slash of all species becomes highly flammable within a few weeks following timber cutting; thereafter there is a gradual decline in flammability. Slash-treatment measures, therefore, result in the greatest hazard reduction when they can be performed quickly after timber cutting.

Species has an important influence on logging slash flammability. Western hemlock and western larch are examples of species which drop their needles so rapidly that a major reduction in flammability occurs by the second fire season in the life cycle of the slash. Species which retain their needles, especially the pines and western redcedar, show a much smaller reduction in flammability with aging.

Flammability ratings and fire behavior also vary widely by other species characteristics. Species such as the pines, which contain a large amount of needle surface in comparison to stem, branch, and other larger-sized-woody surfaces, exhibit more violent burning characteristics.

Amount of slash is perhaps the most important single factor influencing flammability. Burning experiments at the Priest River Experimental Forest show clearly that heat and rate-of-spread of slash fires increase with the amount of slash present. The effects of amount of slash are especially evident in slash only a few weeks old. However, heavy slash concentrations retain high flammability ratings even after aging for two and three seasons.

The results of the logging slash flammability research will be summarized in a publication now being prepared.

### Slash Measurement

Work continued on the development of slash-yield tables which will show the probable quantity of slash per thousand board feet of timber cut according to species, age of stand, site factors, and stand density. During 1956 tree crowns were measured on additional species and age classes. Data from the tree crown measurements in nine major species of the Intermountain West are now being analyzed.

The results of this analysis should indicate the amount of additional field data needed for the development of satisfactory slash-yield tables.

## Slash Disposal Methods

Slash chipping was tested in conjunction with dozer piling and hand piling during 1956 on experiments initiated on the St. Joe National Forest. The purpose of these experiments carried out on timber sales is to determine the feasibility of chipping as a means of slash disposal in Intermountain forests. The chipper equipment is mounted on a tractor-bulldozer to provide complete mobility over the timber sale area.

Previous experiments at the Priest River Experimental Forest have shown conclusively that chipping is an effective means for reducing the hazard of logging slash. Preliminary results of the St. Joe National Forest experiments show that chipping may be employed as an important means of slash disposal, but when used alone is not a completely satisfactory method. Chipping shows up best when employed in conjunction with other methods, such as dozer piling, hand piling, and spot burning. Slash concentrations, residual stand, erosion problems, and many other factors vary widely over a timber sale area. Best slash treatments often require a combination of methods.

Application of chipping as a method of slash disposal requires keen analysis of many flammability factors as well as silvicultural and other resource management considerations. Also, determination of when and where to employ chipping requires careful analysis of cost factors. Experiments of the type initiated during 1956 should provide valuable information upon which to base decisions on slash disposal methods.

## FOREST ECONOMICS RESEARCH

### FOREST SURVEY

### Survey Plans and Techniques

A major step forward was made during the year through more intensive coordination of National Forest Administration's timber inventories for management planning purposes and the nationwide forest survey. A forest inventory field manual was prepared that is now being used by timber management units of National Forest Administration in Regions 1, 2, and 4, as well as on the Forest Survey project. Also, a master plan is being prepared for the use of International Business Machines in compiling inventory data for these same Regions.

### Aerial Photo Interpretation

Over the past years of increasing expense, it has been a major problem to keep costs of forest inventories at a reasonable level. The most effective means have been the installation of streamlined methods of sampling and greater reliance on the use of aerial photographs for stratifying our samples.

Because of the diversified topography encountered in the Rocky Mountain States, questions have been raised about the acceptability of aerial photographs as a sampling tool. Scale changes occur within and between photographs, forest types and timber volumes may be stratified by elevation, and steep topography and dense stands sometimes hamper accurate photo measurements. The over-all objective of our research in photo interpretation is to find out how serious these questions are, and if they are serious, what must be done to answer them. Research to date has been confined to the practical application of aerial photo interpretation to forest inventories. Basic research in photogrammetry has not been attempted.

A number of studies were completed during 1956 with results of three of them reaching the published stage. They included a series of stereograms combining vertical aerial views with horizontal pairs taken with a stereo camera. With these stereograms the interpreter can study both pairs at one orientation of his stereoscope. This combination helps the interpreter bridge the gap between the backlog of horizontal images acquired through field experience, and the store of vertical images he must have to become a successful photo interpreter. They are very fine training tools.

Because the mountainous terrain causes wide variations in scale, it was found necessary to make adjustments in some of the already developed photo interpretation aids. A new parallax wedge was prepared having three times the span of a standard Forest Service wedge and which equals the parallax range of many floating dot instruments.

Three new aerial photo scale protractors for mountainous areas were prepared. They have base photo scales of 1:10,000; 1:15,000; and 1:20,000, and range from 1:7,000 through 1:24,500. This range of scales covers elevation differences of 2,000 to 3,000 feet above and below the datum plane of the base scale.

Additional interpretation aids being developed include a crown cover scale for conifers and an engineers slope percent scale.

Perhaps the most interesting item is the development of "Composite Aerial Volume Tables for Conifers," now being processed for publication. Preliminary tests of these tables have given photo volume estimates within plus or minus 5 to 10 percent of field measured volumes. These results can mean a great deal to the forest manager especially for obtaining preliminary estimates of volume for timber sales. Studies on the application of these tables will continue.

Other studies completed but not yet published include the effect of topographic displacement on dot sampling and the effect of various minimum areas on dot sampling.

Papers on aerial photo volume tables were prepared and delivered by Karl E. Moessner at the annual meeting of the Pacific Northwest section of the American Society of Photogrammetry at Victoria, B.C., and at the annual meeting of the Northwest Scientific Association in Seattle, Washington. Moessner is also participating in the preparation of the chapter on forestry for the Photo Interpretation Manual to be published by the American Society of Photogrammetry.

## Initial Inventory

The field work in Colorado was shifted into high gear at the beginning of the 1956 field season. The Forest Survey Unit through the Rocky Mountain Forest and Range Experiment Station completed final plans for cooperation with Region 2, and ten 2-man crews started measuring field inventory plots. In addition to these men and their leaders, three men were engaged in photo interpretation and delineation of forest cover types and stand size classes within the national forest boundaries.

By the close of the field season, about 3,125,000 acres of forest land had been covered in the field. This is nearly 15 percent of the total area of forest land in Colorado. Of the forest area covered 2,218,000 acres are classed as commercial forest land, or about 26 percent of the total commercial forest land area of the State.

Compilation of data for South Idaho continued and by the end of the year was completed except for derivation of final growth, mortality, and cutting drain statistics. An outline for a combined statistical and analytical report has been prepared and preparation of the report is under way.

## Maintenance Survey

With the assistance of Region 1, the tempo of the reinventory of forest lands in western Montana was increased quite markedly. During 1955 about 1,175,000 acres of forest land were covered by the field inventory. During 1956 2,835,000 acres were inventoried. This brings the total area of forest land covered to 6,663,000 acres. The acreage includes about one-fifth of the commercial forest land of the State.

## Timber Cut

Annual surveys of pole production in the Northern Rocky Mountain Region and Montana's Christmas tree shipments were made. Release of information on 1954 production of wood-using industries is still waiting correlation with Bureau of the Census data.

This was the ninth year that Montana exported more than 3 million Christmas trees. Even then shipments dropped 7 percent from the record 3.5 million trees shipped in 1954. Three counties, Lincoln, Flathead, and Missoula, shipped over 80 percent of the 1955 crop.

Pole production in the Northern Rocky Mountain area built up slightly after a record low in 1954. Output increased about 6 percent over 1954. Number of poles produced by species and state is given in the following tabulation:

| Species | Montana | North Idaho | Northeast Washington | Total | Percent of total |
|---|---|---|---|---|---|
| Western redcedar | 79,438 | 42,755 | 9,667 | 131,860 | 44.8 |
| Lodgepole pine | 95,027 | 0 | 0 | 95,027 | 32.3 |
| Western larch | 33,925 | 15,964 | 11,799 | 61,688 | 20.9 |
| Douglas-fir | 5,828 | 97 | 16 | 5,941 | 2.0 |
| Total | 214,218 | 58,816 | 21,482 | 294,516 | |
| Percent | 72.7 | 20.0 | 7.3 | | 100.0 |

## ECONOMIC STUDIES

During 1956 the industrial study of western Wyoming, southeastern Idaho, and northern Utah, was virtually completed. This study was undertaken cooperatively with Region 4 of the Forest Service. A preliminary draft of the analysis was finished in the fall, and in December a conference was held to discuss and review the findings. As a result of this very thorough inspection, several opportunities were revealed for strengthening or refocusing certain statements. The report has been revised for final review and should be ready for publication early in 1957.

In connection with the study mentioned above, the Robert A. Taft Sanitary Engineering Center (Cincinnati, Ohio) of the Public Health Service made a study of the major streams of southern Idaho and western Wyoming. This analysis, made in cooperation with the health departments of Idaho, Wyoming, Utah, and Oregon, indicates that several stretches on the Snake River in Idaho and one on the Green River in Wyoming are suitable for sulphate pulpmills. This is in respect to the capacities of the streams to handle the pollution loads of pulpmills. The findings of the Public Health Service will be published in a research note.

Because of the growing interest in lodgepole pine as a lumber species, a brief research paper has been prepared summarizing the presently available information on the subject. This report summarizes data recently obtained from two outstanding lodgepole pine sawmills in Montana. The manuscript will be published in 1957.

Another major undertaking was the preparation of a report, "The Future Demand for Rocky Mountain Timber." Using the Forest Service Timber Resource Review as a background, this analysis attempts to interpret the long-range timber outlook in the United States in terms of what it may mean in the way of timber industry opportunities for the Mountain States. The general conclusion seems to be that a long-run tightening of the national timber supply picture opens a bright future for growth of industry in this region. Held up awaiting final revision of the Timber Resource Review, this manuscript likewise will be published in 1957.

A large part of the problems of marketing forest products from the Mountain States relates to long distance and high freight costs. For that reason a complete understanding of the marketing by the states in the Intermountain Station territory requires an appraisal of the freight rate and distribution picture. The opportunity to understand better the transportation problem is enhanced by the fact that certain information on railroad shipments is currently being compiled by the Interstate Commerce Commission. This agency annually publishes waybill statistics for all major commodities. A study has been started to analyze these data to see what light they may shed on the transportation situation. It is difficult to know now how much the study will accomplish, but if the data are as revealing as we hope, they will provide the basis for future marketing studies here and elsewhere.

## RELATED PROJECTS

This Division continued to have Timber Resource Review responsibilities. During 1956, S. Blair Hutchison spent several months in Washington, D. C. assisting in the final revision of the report. He has been concerned mainly with long-range growth projections.

In July, Roscoe B. Herrington was transferred from the Forest Survey project to the economic study section. He will be engaged primarily in marketing studies.

## FOREST UTILIZATION RESEARCH

Timber products output in the Intermountain Station territory has more than doubled in the past decade. Problems in Forest Utilization Research have grown proportionately. There have been significant utilization changes: new fiber-based industries, improved harvesting practices, better sawmills, and a broader integration of resources. The value of past utilization research has paid off. Yet, we are by no means over the hill in answering many of our utilization problems. Despite the great strides that have been made in recent years, much remains to be done. Some notable accomplishments in the Intermountain Station area during the past year have added to our sum of knowledge.

### TIMBER GROWTH AND UTILIZATION RESEARCH

Lumber grade-yield studies have been conducted for more than 40 years in the territory. Although frequently revised, much grade-yield information is now obsolete. Changes in utilization standards, sawmill equipment and practices, and silvicultural methods have necessitated a review of past grade-yield work. Also, it is now becoming increasingly important that stumpage appraisals be made with greater precision than in years past. Not only are timber values in toto increasing but the spread between high quality and low quality lumber is becoming more and more pronounced. It is therefore imperative that the differentiation between high quality and low quality logs be better understood and evaluated.

Three cooperative studies were undertaken this past year in lumber grade-yield recovery: one in Douglas-fir, another in ponderosa pine, and a third in western white pine. The Douglas-fir study was designed to develop criteria for log grades for that species including the effects of compression wood on lumber grade yield. The lumber from 121 trees was tallied, dried, surfaced, and graded. Trees, logs, and green-surfaced lumber were all evaluated for compression wood content. Analysis of these data and publication of results will be done by the Forest Products Laboratory.

A study of ponderosa pine was made in central Idaho to determine the validity and usefulness of the Pacific Northwest ponderosa pine log grade rules for this region. Some 500 logs were tallied; analysis of results is under way. A similar study in western Montana was made for western white pine.

Through the efforts of the Intermountain Regional Log Grade Committee a long-range program has been developed to meet our log grade needs. First, existing log grades in pine and Douglas-fir must be perfected to the extent that they are acceptable for general use.

Second, log grades must be developed for other important species such as lodgepole pine, white fir, Engelmann spruce, and others. Third, log grades must be proof tested as they are developed for each species, including tests for local variations in yield. Last, tree grades must be developed, the ultimate need for timber cruisers and appraisal estimators. It may be 10 years before our needs in log and tree grade work are met.

A solution still needs to be found for the harvesting problem of steep mountain watersheds. Reference has been made to these efforts in past annual reports. The studies now being conducted on the St. Joe National Forest in Avery, Idaho with a 3-ton Wyssen Skyline-Crane continue to demonstrate the feasibility of this particular piece of equipment for logging steep ground. Yet, there are still many questions to be answered concerning the economics of the equipment in terms of production quotas for the western logging industry. A second experiment was undertaken this past year on the Payette National Forest in southern Idaho. The R. G. LeTourneau Corporation installed a portable high-lead logging rig in cooperation with the Brown Tie & Timber Company and the Payette National Forest. This machine demonstrated the feasibility of making heavy-selection cuts or group-selection cuts in the ponderosa pine type in steep country with a minimum of soil disturbance. Some obvious limitations of the equipment became apparent during the course of the experiment, but enough was learned to justify continuation of the experiment and the development of a slightly smaller and lighter machine utilizing the same general principles. It is encouraging, indeed, to find that the loggers are as deeply concerned about finding a solution for harvesting these stands as are the foresters. Indications are that added emphasis will be given harvesting studies during the coming few years with more and more operators willingly joining forces with research foresters in solving this aggravating problem.

A growing interest in fiber utilization has prompted industry to begin inventorying its logging residues. Two intensive studies of logging residues were conducted during this past year, one in eastern Washington and the other in southern Idaho. Although it is not yet conceded that the collection and transportation of logging residues is practical, indications are that trees of a lower general standard can be transported along with high-value material where fiber use is an ultimate outlet. We are a long way from being a region of faggot pickers, but there is a progressively improved trend in woods utilization.

The studies of the behavior of twisting poles continue at Newport, Washington and Libby, Montana. The final results of these two studies will be published in the near future. Indications are that green poles with an affinity for twisting can be bad performers after installation. The direction and the amount of twisting can probably be anticipated and it is still undertain as to whether the pole will ultimately stabilize or not. Still to be studied are the frequency of occurrence of twisting poles, the fundamental causes for the formation of spiral grain, and the possibilities for eliminating or at least minimizing this abnormality. Such studies will involve the physiology, genetics, environmental factors, and microstructure of trees.

## PULP AND PAPER

As early as 1915, studies were made of the pulp and paper possibilities for western Montana. A specific study in the Kootenai National Forest at that early time has, after more than 40 years, come to fruition with the announcement by the St. Regis Paper Company of plans for a pulp mill near Libby, Montana. Simultaneously, the Waldorf Paper Products, Inc. have started construction of a kraft pulp mill on the Clarks Fork River near Missoula, Montana. These two announcements offer proof of the validity of recent work done by Forest Utilization Research in which the possibilities for fiber utilization in the northern Rocky Mountain area were emphasized. It is now apparent that the development of a substantial pulp and paper industry in this area has just begun. It is anticipated, from the inquiries received from industry, that additional facilities will be established in the course of time.

Western hemlock is an important species to the paper industry in the Inland Empire. Rot has been a problem of major concern to the paper maker and has necessitated the exclusion of much raw material in the past. A cooperative study of hemlock chip and pulp yield from defective hemlock demonstrates that losses are less significant than was anticipated. It means that a broader use of this valuable species will be possible and pulp capacity in the Inland Empire can be sustained or increased.

With the installation of new pulp facilities, in addition to increases by established pulp mills, it is imperative that the analysis of industry opportunities in the Station's territory be accelerated. This division has worked closely with the Division of Forest Economics in appraising industry possibilities in eastern Montana, and more recently in the headwaters area of the Colorado River. Broadly speaking, it can be said that there are ample wood resources for a substantial pulp industry. Limitations of water, markets, and transportation are localized. Special reports from time to time will point out where possible sites lie.

## PHYSICS AND ENGINEERING

The final samples of lodgepole pine, western larch, and western redcedar were selected for the American Society of Testing Materials strength evaluation. Commercial poles of 5 species are being tested cooperatively by the Forest Products Laboratory. Last year the Division reported on the selection of untreated material. This year the selection was of treated poles which will be tested for strength and reported in a special publication of the ASTM. The results of this study, whatever they turn out to be, will be of considerable value to the pole industry of Montana and Idaho, an important segment of our forest industry. Care in the selection of the test material was stressed so that a true reflection of the representative timber going into commercial use was sampled. Since strength is so closely related to specific gravity, selection was made on the basis of a range and an average of gravity.

Some of the smaller sawmills in Utah are manufacturing rough lumber for industrial use. Typical uses are car stakes and blocking used in shipping fabricated steel by railroad. Present Railway Association rules prohibit the use of some of our more common species, principally lodgepole pine. An effort is being made to have the Railroad Rules Committee revise their specifications to include some of these regional species.

The bigger sawmills recognize the importance of well managed and operated dry kilns. Some mills are adding dry kilns to operations that have heretofore had none, and some of the major producers are constructing or remodeling existing kilns to do a better job and to increase their capacity. One such mill just completed a multimillion dollar installation and is now able to reduce its drying time by almost 30 percent. At the same time, the quality of output is apparently improved.

The drying of poles, particularly in northern Montana, is a short-seasoned program when air drying alone is used. One of the major pole producers has experimented successfully with a dry kiln for handling full-length poles. Besides shortening the drying period by a considerable amount, drying in this kiln improves the surface characteristics of the wood, making it better suited for the treating cylinder.

## TIMBER PROCESSING

The plywood industry is slowly gaining in its installed capacity and output in this region. There is little likelihood that plywood production will ever rival that of the Pacific Northwest or California, but there are indications that there is ample opportunity for a steady and calculated growth. There was a good market this year for sheathing grades of Douglas-fir plywood and other species, including ponderosa pine, western larch, and cottonwood. There was also a good market for sliced pine veneer which is being produced at one of the plywood factories. Recent announcement of an additional plywood plant at Whitefish, Montana indicates that opportunities for industrial expansion still exist. The successful production of veneer from our native species has depended to a great extent on the research conducted at the Forest Products Laboratory and in the field.

There was continued interest in the production of paper-overlaid lumber by two operators in this region the past year. One produces a thin lumber with a high grade paper covering designed for exterior paneling use. The other produces a lower grade lumber and low-grade paper covering primarily designed for sheathing use. Both of these operations are on the threshold of fullscale commercial production and there is optimism about the ultimate opportunities for producing and selling paper overlaid lumber. Information developed by the Forest Products Laboratory in this new use of wood and paper has been the starting point for all of the pilot plant operations to date.

One company has demonstrated that 1 by 4's can be face laminated successfully by continuous processing into suitable 2 by 4's for studs, rafters, and light joists. Material for pilot plant testing has been produced; commercial production is ultimately contemplated. Present equipment must be modified to put the operation on a full commercial basis, however.

## WOOD CHEMISTRY

There is some industrial research being done on the use of wood derivatives. The pulp and paper industry is seeking new outlets for waste liquor. There is renewed interest in the production of commercial galactan from western larch. So far there are no known commercial enterprises based on wood chemistry but indications are that such industries may be forthcoming.

There is one commercial charcoal plant in the region using river bottom hardwoods, salvaged shade trees, and some softwood sawmill residues as raw material. The operation is of the block-kiln type and is managed much the same as block kilns elsewhere. It is felt that there are additional opportunities in this region, particularly in the desert areas of Utah and Nevada, for more charcoal plants.

Certainly the market, particularly on the Pacific Coast, can absorb increased production from this region. There seems to be no letup in the demand for charcoal with a growing trend toward briquetted charcoal.

## WOOD PRESERVATION

How much deterioration occurs in logs that are cold decked for as long as 2 or 3 years either with or without water spray is a problem which must be studied in the near future. Considerable volumes of timber are so handled and the aggregate dollar value of inventory decks is high. This problem has been studied only on an extensive basis up until now.

The division has cooperated with the Forest Products Laboratory and the Bolidens Gruvaktiebolag, Skelleftchamn, Sweden in testing of a new process of treating difficult-to-treat woods. The Station is particularly interested in western larch, Inland Douglas-fir, and Engelmann spruce, all three species in which heartwood penetration is difficult. The claims of the Henriksson process are that it can obtain ample penetration and retention in these difficult species. No tests have been conducted as yet but sample material has been shipped to the Forest Products Laboratory and to Sweden for pilot plant experiments.

The Division of Forest Utilization Research will continue to work closely with the other divisions of the Station both in the planning and conduct of experiments. Almost every study in Forest Management and many in Forest Economics have some implication in utilization. Likewise, studies in utilization involve work of these two other divisions. It is imperative, then, that the various divisions work closely together in the development of program plans and experiments. This division will continue to serve as the eyes and ears of the Forest Products Laboratory both in evaluating industry needs and in bringing the results of research as quickly as possible to the forest industries. The Station operates in a big and complex geographic area with a wide assortment of forest enterprises, each requiring a certain amount of specialized assistance. The division will continue to serve them within its capacity.

# RANGE MANAGEMENT RESEARCH

Problem analyses are a continuing part of effective long-range research. Where a new research program is being undertaken or a going program is being revised, a formal analysis of land-management and research problems is invaluable. A summary analysis of range problems in the southern (Region 4) part of the Intermountain Station's territory was presented in our annual report for 1952. At present the formulation of range-research problem analyses is going forward actively at the Missoula, Inland Empire, and Boise Research Centers. Highlights of the analysis for the Missoula Center are presented in the following pages, together with selected items of progress from going research projects.

## RANGE PROBLEMS AND RESEARCH NEEDS IN MONTANA

In general, Montana ranges appear to be in better condition than those of many other western states. This may be the result of more judicious management than in other areas or perhaps of a shorter grazing season and a more favorable climate. At any rate, there has been a tendency to minimize Montana range problems through comparison with other areas where depletion is much more severe. Although some solace can possibly be derived from such comparisons, it is readily apparent that Montana, too, has many range problems that cannot be ignored merely because they are less advanced than elsewhere.

### Problems

During the past century most Montana ranges, like ranges elsewhere in the West, have been damaged by grazing of domestic livestock or big-game animals. In some cases damage has not been serious, consisting of but minor losses in the most desirable forage plants and replacement by less desirable species. In other instances where grazing has been severe, conditions have been greatly altered--undesirable species have invaded, plant cover has been reduced, soil erosion has been accelerated, and forage values have diminished. The chief range management problem, then, is one of restoration, and it is, of course, most acute on areas where soil is being rapidly eroded. Some of the areas that have been damaged most are high altitude herblands, big-game winter ranges, and foothills used primarily for spring and fall livestock range.

The grass-forb ranges occurring at high elevations throughout western Montana vary from rather extensive areas in some mountains to small openings in the forest communities of others. Although these herblands may differ greatly in topography, soil, vegetation, and degree of depletion, they have many things in common. All are subject to extremes in weather--a short growing season with possible killing frosts at any time, abundant precipitation often coming in high-intensity storms, rapid temperature changes, intense light, and high winds. Steep slopes are common, and once these start to "unravel," soil loss is often rapid. Grazing is mostly by sheep and is concentrated in a short season that corresponds rather closely with the growing period of the plants.

Casual inspections of a number of ranges indicate that practically all have suffered damage in some degree. Although the condition pattern is complex, varying with slope, exposure, soil type, and accessibility, it is readily apparent that plant cover of extensive areas has been greatly reduced and that accelerated erosion is taking place. In some areas practically all vegetation has been destroyed and erosion is progressing at a very rapid rate. As a matter of fact, all soil has been lost in a few places, exposing bedrock. Examples of these high-elevation problem ranges are on the Big Timber, Gardiner, and Hebgen districts of the Gallatin National Forest, the Sheridan district of the Beaverhead, and the Lincoln district of the Helena. Undoubtedly there are many others on practically every national forest or mountain mass in Montana. These high ranges are particularly important from the watershed standpoint, probably yielding more water per acre than any other type. Since runoff and erosion originating here can cause serious flood and siltation damage, it is particularly necessary that vegetation and soil of these herblands be stabilized.

Most south-facing slopes in western Montana may be regarded as big-game winter range. Although having wide vegetal and elevational variation, these winter ranges have one thing in common--a relatively light snow cover. Condition is generally unsatisfactory. On extensive areas, desirable browse species such as mountain mahogany and bitterbrush are severely hedged and the plants are low in vigor. On some ranges most of the shrubs are already dead. Perennial grass and forb cover has also been greatly reduced, exposing much bare ground and allowing invasion of annuals. Accelerated erosion is widespread, and on many spots much of the normally shallow soil mantle has been lost.

The ranges of the foothills and valleys normally receive their greatest use from livestock in spring and fall. Some are subjected to additional grazing pressure by antelope at all seasons, by elk and deer in winter, or by livestock during summer. Vegetation of these ranges has also been greatly influenced by such animal life as grasshoppers, crickets, squirrels, gophers, mice, and rabbits. Furthermore, cultivation and subsequent abandonment has often been responsible for extreme changes. As a result, the original vegetation has been largely destroyed, and it is difficult to find even small areas that appear to be representative of pristine conditions. Although considerable bare ground has been exposed, soil erosion generally has not been severe, probably because of the rather gentle topography.

Ranges used primarily by cattle in summer are often in better condition than others, but it must not be assumed that they are entirely free of problems. Many of these are presently in no better than fair condition, and on many a downward trend is evident. Most of these ranges, however, should respond readily to improved management. On a few areas, deterioration has reached an advanced stage. Examples of such depleted conditions can be found on the Rock Creek district of the Custer National Forest, the Hebgen district of the Gallatin, the Whitehall district of the Deerlodge, and the Sheridan district of the Beaverhead.

On many of these ranges, problems have been intensified by loose, granitic soils which are naturally droughty and erosible. With loss of fine materials, water-holding capacity and fertility have been lowered, and conditions have become less and less suitable for growth of vegetation. Such soils have developed on granites from the Idaho and Boulder batholiths as well as on Archean gneisses and associated granitic intrusions, and occur mainly on and adjacent to portions of the Bitterroot, Beaverhead, Deerlodge, Helena, and Gallatin National Forests.

An important problem involving grazing and forest regeneration arises mainly from the common tendency for dominance by either the animals or the trees and requires the establishment of a balance between the two land uses. On some areas, grazing is controlling the vegetation by preventing establishment of coniferous reproduction, whereas on others forest regeneration is controlling grazing use by crowding out forage plants. Although depleted vegetation and accelerated erosion may intensify problems on some areas, for the most part plant cover is adequate for soil protection. In this respect, timber-grazing problems differ greatly from those previously considered. Damage to tree reproduction by grazing animals is serious, particularly on certain big-game winter ranges. Conditions are especially critical in Lincoln County where maintenance of the most valuable timber species, ponderosa pine, is being threatened by grazing of white-tailed deer. Elsewhere reproduction of both lodgepole pine and Douglas-fir is being subjected to various grazing pressures by both livestock and big game with only limited knowledge of effects of such use. Livestock, of course, are much easier to control than big game, but at present there is little basis for total exclusion or application of various systems of management. On the other side of the problem is the reduction of acreages being opened by fire at the same time that big-game populations are increasing markedly. Although new areas being opened by logging are partially compensating, silvicultural treatments aimed at immediate regeneration tend to reduce forage values.

As indicated in the 1955 annual report, spread of noxious weeds on both range and forest lands is another major problem. As would be expected, invasion by these weeds has been most rapid on areas where the native vegetation has been severely disturbed, as on overgrazed ranges and cut-over timber lands. Some of the most abundant are goatweed, Canada thistle, knapweed, wyethia, tarweed, and leafy spurge.

## Research Needs

It should be noted at the outset that action based on present knowledge can improve a number of unsatisfactory range conditions, and therefore research needs are not necessarily greatest on problems listed as being most critical. Although all the studies included herein are considered essential to proper management of the resource, an attempt has been made to discuss them in order of decreasing importance.

The most urgent need appears to be ecological studies of the various range types in order to provide a basis for improved management. It is especially important to know the potential of particular sites, patterns of succession and destructive change, and effects of the various environmental factors. In the past, management has often been ineffective because lack of such information has prevented proper classification of range condition, recognition of trend and its rate of progression, and determination of reasons for observed changes. Not only is it important to know the effects of grazing by domestic livestock, but also, effects of other factors in the range complex such as big game, weather, fire, rodents, insects, and soil-dwelling microfauna.

Also of high priority are studies of timber-grazing relations to determine how satisfactory reproduction can be achieved under use by livestock and big game. As already mentioned, establishment of ponderosa pine seedlings on winter deer range is of special importance. Effects of grazing on regeneration of lodgepole pine and Douglas-fir are also in need of study. On the other hand, investigations should be made to determine what silvicultural treatments create the most desirable habitats for game. Certain cutting practices or slash disposal methods might well serve to encourage forage plants, particularly browse. Increasing forage production by seeding herbaceous and shrubby species may also have a place in some areas.

Livestock-game relations should be studied to determine relative effects on the various types of vegetation, how to recognize utilization by different animals, and to what degree they compete for forage. So far, this field of research has been given but little attention. Until such information is available, there can be no sound basis for management of ranges grazed by both livestock and big game.

Artificial revegetation research is needed in two special fields: high altitude herblands and winter game ranges. Studies of adapted grasses and methods of planting have provided guides for successful seeding of many ranges, but the high elevations have been largely neglected. In view of the depleted condition of many high ranges, it appears that artificial revegetation may be the only means of restoration that can be accomplished within a reasonable period. Winter range for big game is particularly short, and the situation is becoming more and more critical as a result of continuing depletion of these areas. At least part of the solution to this problem must come from research on habitat improvement, particularly browse revegetation.

Ecological life history studies of the various noxious weeds should be made. Although methods have been developed for eradicating many of the weeds, control is only temporary unless provisions are made to prevent reinvasion. Furthermore, certain direct control methods that are satisfactory on cultivated lands are too expensive for use on the range. For these reasons ecological studies are necessary to determine what conditions are necessary to prevent reinvasion following eradication or how indirect control through management can be achieved.

Research on grazing summer livestock ranges has been inadequate not only in Montana but in the entire Intermountain area. Results from studies in this region on management of spring-fall and winter ranges are partially applicable, as well as those from summer range studies in other regions; however, local intensity, season, and system studies are needed to provide satisfactory guides for management of Montana summer ranges. Although management studies are needed on ranges at several different altitudes, first consideration should probably be given to those at intermediate elevations where condition is generally fair or better, but trend is often downward. Since these are mostly cattle ranges, this class of stock should be used in grazing management studies. If studies can also be made on high-altitude herblands, sheep should be used. In connection with management studies, it would be well to investigate the utility of artificial disturbances to vegetation and soil as a means of separating effects of forage utilization and trampling which are confounded in actual grazing trials.

A universal need that should not be overlooked is methodology for measuring vegetation and changes therein. Although many advances have been made in this field, no methods have yet been developed that are wholly successful. Opportunities to explore methodology, therefore, should not be ignored, particularly when tests can be integrated with other range research projects.

## Tentative Plans

At present only one man is assigned to the range research project in Montana. In view of the current emphasis on allotment analysis and the need for criteria of condition and trend, his major effort will be directed at ecological studies of the important range types. In addition to studies of site potential, patterns of change, and effects of environmental factors, it may also be possible to include some life history studies of individual species, particularly noxious weeds. Most of these studies should be planned on a long-term basis, but some "quickie" studies will undoubtedly suffice to provide immediate answers.

If a second man can be added to the project, he will work primarily in the field of grazing in relation to forest regeneration. The problem of obtaining satisfactory tree reproduction on areas grazed by big game should receive highest priority, but effects of livestock grazing should also be studied. Such studies will include consideration of methods for increasing forage production on cut-over areas.

It would be desirable to have a third man assigned to the project to work on game-livestock relations on nontimbered ranges, particularly east of the Continental Divide. He could also carry on browse revegetation studies for rehabilitation of winter game ranges.

Before initiating studies in the field of game range management, possibilities of cooperation with other agencies and organizations will be fully explored. Also, careful consideration will be given to division of research activities between men.

It would be desirable to resume livestock management studies at the Vigilante Experimental Range, but this should not be done unless adequate financing can be assured. In the past the program has been largely one of expediency because of insufficient funds, and consequently was somewhat ineffective in providing guides for management of summer ranges. An effective program at this experimental range would require at least one permanent man with temporary field assistant help. In view of the need for information on management of mountain ranges, it is unfortunate that full advantage cannot be taken of the facilities available at Vigilante.

# BIG GAME-LIVESTOCK RANGE RELATIONS

## Effects of Heavy Grazing by Deer and Sheep

Excessive stocking by deer and sheep has produced characteristic ecological changes in foothill ranges of Utah. Table 5 illustrates such changes in the juniper-sagebrush-bitterbrush type grazed by deer in winter and by sheep in spring and fall.

Table 5.--Plant growth and range condition in relation to grazing use on juniper-sagebrush-bitterbrush type

| Forage | Good condition range | Range heavily overgrazed by | | |
|---|---|---|---|---|
| | | Sheep only | Sheep and deer | Sheep + severe deer use |
| | Plant growth-lbs. per acre air-dry | | | |
| Bitterbrush | 730 | 440 | 300 | 15 |
| Sagebrush | 470 | 935 | 160 | 3 |
| Other shrubs, mainly rabbitbrush | 90 | | | |
| Perennial forbs | 330 | Trace | 25 | Trace |
| Perennial grasses | 330 | 10 | 20 | 2 |
| Total | 1,950 | 1,385 | 505 | 20 |
| Bare soil-percentage | 7.4 | 37.6 | 46.5 | 57.3 |

Good condition range had an effective ground cover of mixed grasses, forbs, and browse well suited to both deer and livestock grazing.

On overgrazed sheep range, practically all perennial forbs had been eliminated and perennial grasses occurred only under protection of shrubs. Bitterbrush, which is palatable to sheep as well as deer, showed signs of hedging but was still fairly vigorous. However, no young plants under 14 years old were present, indicating unsatisfactory condition for this important shrub. Sagebrush was vigorous and reproducing, but despite its apparent increase, 37.6 percent of the soil was bare and much topsoil had been lost. Annuals, particularly cheatgrass, are often abundant on such areas in years of plentiful rainfall.

On range overgrazed by both deer and sheep, shrubs as well as herbs had decreased, with a further increase in bare ground. Bitterbrush, although it still produced considerable forage, was severely hedged and no young plants below 15 years of age were present.

Heavy sheep use accompanied by severe winter deer browsing resulted in destruction of both bitterbrush and sagebrush. Under such severe overstocking all available green shoots of both species are utilized. But because sagebrush is less able to "hedge up" and protect itself, and because it does not sprout from the base or from older stems as does the more palatable bitterbrush, it succumbs sooner to severe overuse by deer. With this destruction of browse, additional bare soil is exposed to erosion.

## Range Condition Affects Deer-Herd Productivity

Cooperative studies with the U. S. Fish and Wildlife Service and Utah State Fish and Game Department show that condition of summer range has a decided influence on deer-herd productivity. Table 6 compares forage and deer-herd productivity on a severely overstocked and depleted summer range in central Utah with one moderately stocked and in good condition for deer in southern Idaho. The winter range of both herds is in poor condition.

Table 6.--Deer-herd productivity in relation to production of good and fair deer forage on two summer ranges in contrasting degrees of condition

|  | Depleted range | Good-condition range |
|---|---|---|
| Forage present, pounds per acre, air-dry |  |  |
| Good deer forage | 104 | 598 |
| Fair deer forage | 160 | 227 |
| Total good and fair forage | 264 | 825 |
| Deer-herd productivity |  |  |
| Ovulation rate per doe | 1.31 | 1.95 |
| Fetus rate per doe | 1.18 | 1.85 |
| Average weight in pounds of fawns in October | 38.5 | 60.5 |

All good and fair forage species on the depleted area were heavily utilized by September, while on the better range good forage was plentiful season long.

Good forage species on the moderately stocked range included a variety of both herbs and shrubs. Several of these same choice plants occurred only as remnants on the depleted range, indicating that at one time this range also supported a cover of good deer forage.

Deer-herd productivity, as indicated by both ovulation and fetus rates, was about 65 percent greater from summer range in good condition than from depleted range. Likewise, weight of fawns in October was nearly 65 percent greater. It is reasonable to expect that there would be an even greater difference in net increase in the two herds, since the fawn drop and survival are known to be greater for deer in good condition than for deer suffering from malnutrition.

Although most deer range problems occur on winter range, it is clear that condition of summer range is also of material importance. This is true not only from the standpoint of forage production and watershed protection, but also from the standpoint of efficient deer-herd productivity.

## SUMMER RANGE

### Forage Utilization in the Aspen Type

It is often observed where openings occur adjacent to large stands of aspen that the herbaceous vegetation of the openings is sparser, shorter, and made up of less desirable forage species than the more luxuriant vegetation under aspen. On some depleted ranges, for example, the openings may be dominated by annual weeds with very few perennial species, while the adjacent understory vegetation may be a fair stand of perennials of moderate or low palatability.

One of the factors that might be responsible for this difference in ground-cover vegetation is a parallel difference in grazing pressure--if one exists. One sometimes hears it said that utilization by grazing animals is closer in openings than under aspen. Attempts to trace down the origin of these statements in the form of factual observations, however, have led nowhere.

To investigate this question as part of a study of several years' standing on the productivity potential of the aspen type, some formal observations of utilization were made in 1955 on the Manti-LaSal National Forest in central Utah. For most of these observations, parallel transects of meter square plots--usually 5 or 10 in a given location--were run in openings and under nearby aspens, and on these plots percentage-utilization estimates were made of total production by species.

Although the observations are classified with respect to sheep and cattle grazing, some utilization was by mule deer. In most instances, deer utilization could not be segregated from utilization by livestock. It is believed that the amount of forage consumed by livestock on these study areas was much greater than the amount consumed by deer.

The Olsen Creek area dealt with in table 7 had been grazed by sheep one or two weeks before the July 16 observations. In general there is not much difference between the utilization measurements under aspen and in the opening, although there is a slight tendency for utilization figures in the opening to be the higher. Only in the cases of *Vicia* and *Viola* do the differences appear to be significant.

Table 7.--Utilization by sheep under aspen and in adjacent opening in early summer and late fall, 1955, Olsen Creek

| Forage species | July 16 | | October 19 | |
|---|---|---|---|---|
| | Under aspen | Open | Under aspen | Open |
| | Percent | Percent | Percent | Percent |
| Agropyron trachycaulum | 4 | 4 | 7 | [1]7 |
| Bromus carinatus | 9 | 10 | 13 | [1]16 |
| Poa pratensis | 12 | 20 | 9 | 66 |
| Achillea lanulosa | 6 | 13 | - | - |
| Aster chilensis | 35 | 39 | 13 | 46 |
| Penstemon rydbergii | 20 | 22 | - | - |
| Taraxacum officinale | 33 | 42 | 19 | [1]21 |
| Vicia americana | 7 | 26 | - | - |
| Viguiera multiflora | 25 | 31 | 9 | 24 |
| Viola nuttallii | 4 | 20 | - | - |

[1] Utilization of fall regrowth. Most of summer growth utilized.

At first glance, the figures for October 19 appear to be little more impressive, only those for *Aster* and *Viguiera* being greatly different. In fact, however, utilization in the opening was much the heavier. The figures recorded are only for utilization on regrowth for *Agropyron*, *Bromus*, and *Taraxacum* when actually most of the season's growth had been grazed. The amount utilized was at least two-thirds or three-fourths of that produced, and the vegetation was too far gone to permit satisfactory estimates. The figures for utilization under aspen, in contrast, reflect utilization based on total growth. It may be wondered why some utilization figures under aspen are shown to be greater in July than in October. The reason is probably that the total amount of growth was greater in October.

Similar observations on cattle range in Twelvemile Canyon, with estimates based upon total production, show markedly heavier use in openings than under aspen (table 8). Higher up in Twelvemile Canyon, on areas that had not been grazed by cattle at the earlier date of observation, there were also marked differences by October 20 (table 9).

Table 8.--Utilization by cattle under aspen and in adjacent opening in early summer and late fall, 1955, Twelvemile Canyon

| Forage species | July 15 | | October 20 | |
|---|---|---|---|---|
| | Under aspen | Open | Under aspen | Open |
| | Percent | Percent | Percent | Percent |
| Agropyron trachycaulum | 4 | 30 | 12 | 87 |
| Bromus carinatus | 3 | 17 | 18 | 88 |
| Taraxacum officinale | 5 | 26 | - | - |
| Vicia americana | 2 | 8 | - | - |

Table 9.--Utilization by cattle under aspen and in adjacent openings, October 20, 1955, at two areas north of Mt. Baldy Ranger Station

| Forage species | Area 1 | | Area 2 | |
|---|---|---|---|---|
| | Under aspen | Open | Under aspen | Open |
| | Percent | Percent | Percent | Percent |
| Agropyron trachycaulum | 38 | 90 | 6 | 56 |
| Bromus carinatus | 54 | 86 | 16 | 55 |

Several comparisons in Ephraim Canyon reveal the same essential pattern on common-use range. In each case utilization is heavier in openings than under aspen.

The foregoing figures, which vary greatly from place to place but maintain a remarkably consistent pattern whether sheep or cattle, or both, are the principal grazing animals, show definitely that grazing pressure is greater in openings than under an aspen canopy. Why this should be so is not known. It seems probable, from the work of Welton and Morris on woodland pasture in Ohio (Jour. Forestry 26: 794-796, 1928) that unshaded plants in the open are able to manufacture more sugars than those in the shade of aspens, and so are relished more by the animals.

## Plant Production on Seeded and Unseeded Subalpine Range

In 1951 the Manti-LaSal National Forest seeded an area of 435 acres in the head of Manti Canyon at an elevation of about 10,000 feet. This was depleted cattle range, dominated by forbs that were for the most part unpalatable to cattle. They included *Geranium richardsoni*, *Artemisia discolor*, and *Viola nuttallii* as dominants; grasses were very scarce. From 50 to 75 percent of the soil surface was exposed over extensive areas, where no more than 25 to 30 percent should be exposed on this important watershed if it were in good condition.

Portions of the area were left unseeded in order to provide comparisons of seeded and unseeded range. The information in table 10 summarizes results from comparisons of 60 paired 9.6 sq. ft. plots on the seeded range and comparable unseeded range in 1956. Cover was determined by use of the point analyzer, and production by the weight-estimate method.

Table 10.--Cover and green-weight production on unseeded and artificially seeded subalpine range at the head of Manti Canyon four years after planting

| Type of cover | Cover |  | Production per acre |  |
|---|---|---|---|---|
|  | Seeded | Unseeded | Seeded | Unseeded |
|  | Percent | Percent | Pounds | Pounds |
| Grasses | 19 | 5 | 1,514 | 220 |
| Forbs | 11 | 26 | 783 | 1,748 |
| Litter | 10 | 10 | - | - |
| Total | 40 | 41 | 2,297 | 1,968 |

Total cover under the two conditions is about the same; but on the seeded range, grasses make up about half the total, and on the unseeded range, forbs make up nearly two-thirds of the total. This is what one would expect, since plowing destroyed many of the forbs, and most of the species planted were grasses. It is notable that litter on the seeded areas has built up in 4 years to make as much cover as that on the unseeded areas. This reflects both the rapid decay of litter from forbs and the relative persistence of the more highly lignified grass litter.

The production figures show that total production (green weight) is 329 pounds per acre greater on the seeded than on the unseeded areas. Grasses produced 1,294 pounds per acre more on the seeded, and forbs 965 pounds per acre more on the unseeded range. Actually, the unseeded areas had improved during the period since seeding because of relief from grazing, and grasses are more abundant there now than they were 4 years ago. During the past 2 years, when some grazing has been permitted, the cattle have tended to concentrate on the seeded areas so that the unseeded range has been grazed less heavily than formerly.

This high-mountain planting demonstrates that, through seeding palatable grasses, cattle can be encouraged to forsake formerly overgrazed portions of the range to allow their natural recovery. A problem may arise in getting the desired utilization on nonseeded areas, but perhaps as their condition improves they will become more attractive to cattle.

## SPRING-FALL RANGE

### Seed Source of Sagebrush Reproduction on Burns

For a number of years studies have been conducted at the Upper Snake River Experimental Range to determine the immediate source of seed that gives rise to sagebrush seedlings on burned-over areas. These studies indicate that sagebrush seedlings arise both from seed introduced onto burns from adjacent unburned seed sources and from seed stored in the soil. Wind-borne seed appears to be restricted to areas fairly near the unburned seed source; residual seed appears to be by far the greater source of seedlings on the major portion of large burned-over areas.

### Root Nematodes in Crested Wheatgrass

Decline in crested wheatgrass stands after a few years of high production has been noted by many workers. Among the explanations offered for this decline are exhaustion of soil nitrogen and "decadence" of the plants. Recent research suggests that a buildup of parasitic root nematodes may be a cause.

Interest in this subject goes back several years. In 1955 Mr. Gerald Thorne (then of the U. S. Nematology Field Laboratory, Salt Lake City; now a member of the faculty of the University of Wisconsin) collected soil samples at the Benmore Experimental Range and in Ephraim Canyon, mainly in experimental plantings. From these few samples he distinguished 19 species of nematodes at Benmore and 21 in Ephraim Canyon. In each of these samples there were hundreds of individual nematodes per pound of soil. Some were known to be ectoparasitic feeders on plant roots, many were saprophagous, feeding on decaying organic matter, some were predators feeding on different soil organisms, including other nematodes, while the food habits of several were unknown. Mr. Thorne concluded that *Tylenchorhynchus cylindricus*, which was found in all six samples at Benmore, was probably the most important species at that experimental range. These nematodes were washed from soil samples: it remained to be shown that nematodes did in fact parasitize crested wheatgrass roots.

With the help of Mr. Thorne and his successor in the Nematology Field Laboratory, Mr. Edsel Jorgensen, a cooperative-aid project was set up by the Intermountain Station with the University of Utah. A student, Mr. David Havertz, was engaged to explore the subject further.

Mr. Havertz was successful in demonstrating the presence, in stained microscopic slides, of several individuals of *Nothotylenchys* (*acris*?), an endoparasite, in the roots of crested wheatgrass. The fact that nematodes do indeed parasitize crested wheatgrass was thus established.

In a subsequent study Mr. Havertz fumigated soil known to be infested with nematodes, using ethylene dibromide. A series of 10 clay pots was planted with this fumigated soil, and a parallel series of 10 pots with comparable unfumigated soil. Crested wheatgrass seeds were planted in each pot; and 21 days after planting, the seedlings were thinned to make the paired pots as comparable as possible. The plants were watered each day in the greenhouse. The measurements recorded in table 11 were taken on pairs of pots at four successive dates. Since the soil had to be washed to ascertain nematode numbers, a different pair of pots had to be used at each date.

Table 11.--Height growth of crested wheatgrass plants, and numbers of parasitic nematodes per pound of soil in fumigated and unfumigated greenhouse pots

| Date | Maximum height | | Average height | | No. of nematodes | |
|---|---|---|---|---|---|---|
| | Fumigated | Unfumigated | Fumigated | Unfumigated | Fumigated | Unfumigated |
| | Cm. | Cm. | Cm. | Cm. | Cm. | Cm. |
| Oct. 3 | 37.4 | 21.1 | 24.4 | 15.6 | 0 | 125 |
| Oct. 19 | 28.3 | 24.0 | 23.9 | 18.7 | 0 | 116 |
| Nov. 7 | 28.1 | 28.7 | 24.1 | 21.6 | 0 | [1] 14 |
| Nov. 30 | 32.0 | 25.6 | 22.7 | 15.6 | 0 | 138 |

[1] All female

There is a very marked difference between the paired pots, the plants growing in fumigated soil being much more robust and leafy than those in unfumigated soil. The measurements in table 11 reflect this difference in some degree and suggest, indirectly, that nematodes do have a depressing effect on the growth of crested wheatgrass seedlings. There does not appear to be a progressive effect within the 2-month interval at this stage of crested wheatgrass growth, but the consistent depression (with the exception of one maximum-height measurement) does suggest a real effect. These preliminary results support the hypothesis that nematodes can build up to such proportions as to retard growth of mature plants of crested wheatgrass, and thus make a material reduction in yield.

The commonly observed dying out of portions of crested wheatgrass tufts and, indeed, of entire plants, which many have regarded as "natural," may in fact, then, reflect parasitism.

# WATERSHED MANAGEMENT RESEARCH

Many kinds of watersheds are to be found in the 300-million acre territory within which the Intermountain Station has research responsibilities. A number of conditions affect the manner in which these watersheds dispose of rainfall and snowmelt water as streamflow. Some are of natural origin, such as differences in topographic, geologic, and climatic characteristics. Another is natural variation in vegetation, ranging from widely spaced desert shrubs to densely timbered forests. Other conditions are due to man's activities on the watersheds. Many have been burned--some repeatedly. Others have been crisscrossed with roads. Still others have been dredged and redredged for minerals. Water has been impounded in some and diverted from others. Some valley basins have been drained of stored water by pumping while others have been supplemented by irrigation. Finally, many watersheds have been grazed--some excessively--and others have been logged for timber. All of these activities have changed in some degree the amount, quality, and timing of streamflow yielded by these lands. Some have had a beneficial effect and improved the usability of water. Others have caused detrimental effects.

The effects of land use on the runoff and soil stability characteristics of these forest and range watersheds have given rise to three kinds of watershed management problems:

1. How to restore runoff control and soil stability on watersheds that have been damaged by use.

2. How to maintain such control and stability on undamaged watersheds under continued resource use.

3. How to increase the amounts or improve the timing and quality of water yields.

Satisfactory solutions to these problems require knowledge and understanding of how watersheds receive, store, and yield water; how those hydrologic processes are affected by both natural and man-caused influences, and of the land management practices needed to make best use of them for each intent of watershed management. Development of such knowledge and understanding is the job of the Watershed Management Research Division. During the past year progress was made toward a solution for each of these three problems at various locations in the Station territory.

# WATERSHED MANAGEMENT PROBLEMS AND RESEARCH

A comprehensive analysis of the watershed management problems and research needs in the Northern Region was completed in the past year. This portion of the Station territory embraces the headwaters of two great river basins: the Columbia in western Montana, northern Idaho, and northeastern Washington, and the Missouri in central and eastern Montana and northwestern South Dakota. Following are some of the highlights of that analysis:

## Water Situation in the Columbia and Missouri Basins

The Columbia River discharges an average annual runoff of close to 180 million acre feet. Of this amount approximately 41 million acre feet are produced on 35 million acres in the Northern Region. Of about 59 million acre feet average annual runoff from the Missouri River, approximately 17 million acre feet come from 82 million acres within the Northern Region.

The total invested value of irrigation, power, and flood control developments in the Columbia Basin today is approximately 2 billion dollars. It is estimated that installation of authorized and recommended developments would boost this investment to more than 7 billion dollars. Present invested value of similar developments in the Missouri Basin is about 1.9 billion dollars. Completion of projects under construction plus those authorized and recommended would raise this investment to more than 8 billion dollars. Thus the total value of water-handling facilities that are dependent in large measure upon clean, usable water from Northern Region watershed lands is now nearly 4 billion dollars, but will soon be over 14 billion dollars.

Of primary and recurring concern to people of the Columbia and Missouri River Basins are the problems of:

1. Controlling snowmelt floods, especially along main streams.
2. Preventing sediment in stream channels, reservoirs, water supply systems, irrigation structures, and on farm lands.
3. Improving late summer water supplies for irrigation.
4. Increasing winter streamflow for power generation.
5. Preventing local flash floods from high-intensity rainstorms.

These problems occur in large part because of wide seasonal fluctuations in streamflow. One obvious solution, of course, is large storage dams to regulate streamflow. The projects proposed for these two great rivers should pretty well provide a satisfactory solution for these problems insofar as downstream interests are concerned. Despite this, there are two problems that storage and streamflow regulation through big dams will not handle. One is continuing sedimentation with its attendant storage depletion and high maintenance costs. The other is the fact that large dams will not prevent flood discharges nor water shortages in upper watersheds above them where sizable investments exist in both rural and urban developments. To control floods in upstream reaches and to protect the life of downstream structures and the billions of dollars in industrial and agricultural activities dependent upon them, every effort is needed to control the amount, quality, and timing of streamflow from forest and range watersheds in the Northern Region.

## Physical Characteristics of Watershed Lands in the Northern Region

The Columbia and Missouri Basins are vastly different hydrologically. About 70 percent of the Columbia Basin portion of the Northern Region receives more than 20 inches of precipitation annually; 40 percent receives more than 30 inches, and 4 percent more than 60 inches. By comparison, about 70 percent of the Missouri Basin portion receives less than 15 inches, and only 1 percent receives more than 20 inches.

Average annual runoff from the Columbia River side of the region is equivalent to about 14 area inches. This equals about 41 million acre feet, of which about 27 million originate on 17.8 million acres of national forests. Greatest runoff is from snowmelt in April, May, and June, which are also the months of greatest annual rainfall. About 2.5 area inches of average annual runoff is produced from the Missouri River side of the region. This amounts to about 17 million acre feet, of which about 6.2 million originate on 10.1 million acres of national forests.

About 54 million acres, or 46 percent of the region, are arid lands which ordinarily contribute less than 1 area inch of streamflow annually and this mostly as surface runoff. Ninety-eight percent of these lands occur in the Missouri Basin and are characterized by grass and shrub range, mostly in the plains section of eastern Montana, but also extending into parts of the headwater areas to the west.

Approximately 42 million acres, or 36 percent of the region, are semiarid, producing generally more than 1 inch but less than 10 inches of streamflow each year. These lands produce some seepage flow from snowmelt in the spring but contribute little other than surface runoff during the remainder of the year. About 60 percent of the semiarid lands occur as foothills and low elevation mountains in the upper Missouri Basin, and are characterized partly by ponderosa pine and Douglas-fir forest. In the Columbia Basin these lands occupy substantial areas along the western fringe of the region and in the valley bottoms and low elevation mountains of the Clark's Fork and Flathead River drainages in western Montana. Here, as in the Missouri Basin, grass and shrubs, together with ponderosa pine and Douglas-fir forests, comprise the principal plant cover.

The real water-yielding areas in the region, occupying 18 percent of it, are some 21 million acres of humid lands which produce more than 10 area inches of runoff and which contribute nearly all of their streamflow as seepage flow throughout the year. Eighty-two percent of these lands are in the Columbia Basin, characterized mainly by white pine, larch, spruce-fir, and lodgepole pine forests. In the Missouri Basin they include the higher mountains in central Montana, where the main plant cover is mostly lodgepole pine forest and subalpine-grass-forb range.

Compared with the rest of the Station territory and with some other sections of the western United States, plant cover conditions on Northern Region watershed lands are generally favorable for controlling storm runoff and maintaining soil stability. In recent years substantial improvements in forest and range practices are leaving watersheds in better condition than formerly. Wildfire-burned area has been drastically reduced. Timber cutting has nearly doubled in recent years, but logging roads to harvest this timber are being built to higher standards, with increasing attention given to matters of location, design, and other items of precautionary or corrective nature affecting the control and disposition of water. Considerable progress has been made in livestock and big game adjustments on national forest ranges. However, numerous problems continue to arise from impacts of land use on water and soil. Most of these problems stem from the need for more effective operational measures that will maintain runoff control and soil stability under continued forest and range use.

Notwithstanding favorable plant cover and soil conditions on most watersheds in the Northern Region, there are forest and range areas on which the plant cover and soil have been damaged by past abuse and are not providing adequate watershed protection. These areas, though somewhat less extensive than elsewhere in the Station territory, present equally difficult problems of finding ways to restore control of storm runoff and a series of problems concerned with development of measures for mantle stability on depleted and eroding lands.

Another problem that is becoming continuously more important as industry and agriculture expand, is that of increasing local water supplies. One solution to this problem lies in research that will show how to increase the amount or improve the timing of water yields without seriously stepping up flood frequencies and magnitudes, or sediment loads.

## Watershed Maintenance Problems on Forest Lands

In 1955 about 970 million board feet of timber were cut from national forests of the Northern Region and 830 million board feet from state and private lands. This harvest involved logging activity on some 112,000 acres, of which approximately 62,000 were national forest. It also involved building about 1,600 miles of truck and jammer roads and 1,000 miles of tractor roads. This is equivalent to an area of approximately 10,000 acres from which protective plant cover is annually and permanently removed. Ninety-five percent of the timber harvested came from Columbia River Basin watersheds. Increased logging activity necessary to reach allowable cut levels may well result in baring of soil on as much as 15,000 acres of new roads each year and disturbance of as much as 160,000 additional acres. Current logging and roadbuilding activity, not to mention probable future increases, present some specifically important maintenance problems on forest land.

1. How to lay out and construct logging roads so as to prevent or reduce soil movement into stream channels.
2. How to control drainage from road and skidtrail surfaces.
3. How to cut timber without increasing snowmelt peaks and sediment loads.
4. How to dispose of slash and other logging debris without increasing surface runoff and erosion.

Answers for such problems are most urgently needed in the higher water-yielding areas of the region where the hydrologic effects of timber cutting may have considerable influence on the magnitude of spring snowmelt floods. Of greatest importance in this respect are the white pine, larch, and spruce-fir forests of the upper Columbia Basin in northern Idaho and western Montana.

## Watershed Maintenance Problems on Range Land

Approximately 81 percent of actual livestock grazing use on national forests of the Northern Region now occurs in Montana. Most of it is on watersheds of the upper Missouri Basin. These watersheds also receive additional use from large numbers of game animals. Though there have been reductions in grazing use, some of these ranges are continuing to deteriorate. Some progress has been made in recognizing signs of range-watershed deterioration on badly damaged areas, but there is need for better criteria of range condition and trend for areas which are not so obviously depleted. Required here is more specific knowledge about:

1. How much and what kind of plant cover and soil conditions are needed to cope effectively with high-intensity summer rainfall.

2. How much and by what methods these ranges can be grazed without losing control of storm runoff and soil stability.

Solutions for these problems are needed most urgently on high-elevation grass-forb range, on foothill sagebrush-grass range, and on low shrub-shortgrass range in the plains section in the Missouri Basin where intense rainfall occurs frequently.

## Watershed Restoration Problems on Forest Land

The two most important activities that have contributed to forest watershed damage in the Northern Region are wildfire and poor road construction, the latter especially in connection with logging. Serious accelerated erosion is occurring on some burned areas, especially where the forest has suffered multiple fires. Active erosion also continues from overly steep, poorly located, and improperly constructed roads on some logging areas, even after operations have been completed for some time. These damaged areas need to be stabilized. To accomplish this research needs to learn:

1. What vegetational and mechanical measures are effective for controlling surface runoff and stabilizing soil in eroding burns and on bared road surfaces, cuts, and fills.

2. What the effects of such measures are on water yields and sediment production.

Solutions of these problems requires careful consideration of soils. The loess and granitic soils covering extensive areas of the upper Columbia Basin and the glacial silt soils covering large areas across the northern part of the region are most vulnerable to erosion in the absence of protective plant cover. Forest types having these soils and in which erosion problems are of prime concern are the white pine, larch, and spruce-fir.

## Watershed Restoration Problems on Range Land

It is estimated there are more than 200,000 acres of native range on the national forests of the region and from 2 to 3 million acres outside the forests on which the perennial plant cover is so depleted that measures beyond mere protection from grazing are needed to restore them to satisfactory watershed condition. Research is needed to determine:

1. How to restore runoff control and soil stability by better grazing management methods, by artificial revegetation measures, and by application of mechanical control structures.

2. How watershed restoration measures affect streamflow peaks, water yields, and sediment.

The largest range area in the region for which such answers are needed is abandoned dry-farm land in the plains section of eastern Montana. Other critically depleted areas on which restoration effort is needed occur in the Missouri Basin headwaters on subalpine-grass-forb summer ranges characterized by dolomitic soils and on sagebrush-grass winter ranges on soft sediment and terrace soils.

## Watershed Improvement Problems on Forest Land

Water shortages occur throughout the Missouri Basin in about one year out of ten. Shortages also exist locally in different parts of the Basin almost every year, principally because of large variations in winter precipitation and seasonal flow. Steep profiles of most streams that feed major tributaries in the upper Missouri Basin afford little opportunity for surface storage. Much early-season runoff is lost downstream, leaving upper Basin irrigation dependent upon inadequate summer and fall streamflow. There is need for not only increased supplies of water but, even more importantly, for improvement of streamflow timing to meet irrigation needs.

The best opportunity for creating watershed conditions favorable to improved summer water yields lies in forested watersheds at high elevations where a large part of annual precipitation is snow. Other opportunities exist in heavily forested or wooded streamside areas where large amounts of water are lost by transpiration processes. While it appears that cutting of forests and removal of riparian vegetation can bring about increased water yields, the magnitudes of increase in relation to the treatments required to produce them, and the extent to which timing of streamflow can be altered, are far from being known. It is important also to know whether streamflow peaks are increased in damaging amounts and also whether streamflow can be delayed in terms of weeks or only days. More specifically, research is needed to determine:

1. The best sizes of forest openings and patterns of timber cutting to increase water yield and delay time of streamflow.

2. The greatest amounts of timber that can be safely removed without increasing floods and sedimentation.

3. How, and to what extent, removal of riparian vegetation affects water yield and peak streamflow.

Solutions for these problems are most needed in the lodgepole pine and spruce-fir forests of the upper Missouri Basin.

## Watershed Improvement Problems on Range Land

In view of the importance of snow as a source of water in the Missouri Basin, consideration must be given to possibilities for improving water yields from extensive areas of subalpine-grass-forb range that receive heavy snowfall each year. This range has received little attention as a possibility for water yield improvement by snow management and waterspreading structures. More knowledge is needed of:

1. How drift fences and planted windrows can best be employed for accumulating snow, slowing melt, and delaying streamflow.

2. How and to what extent streamflow from late-melting snowdrifts can be further delayed by waterspreading and storage in the soil mantle.

Considerable evidence indicates that water consumption by deep-rooted shrubs probably exceeds that of more shallow-rooted grass and herbaceous vegetation. Research is needed to determine:

1. How to convert a deep-rooted plant cover to a shallow-rooted one and maintain it.

2. How and to what extent conversion of deep-rooted vegetation to a shallow-rooted cover affects water yield and sediment production.

The lower-lying sagebrush-grass range, especially on deep terrace soils, appears to offer best opportunity for such studies.

## Problem Priorities and Proposed Program

In summary, the most important watershed management problems and the problem areas on which research is needed, in order of priority, are as follows:

1. How to maintain control of snowmelt discharges and mantle stability under the impact of timber harvest cutting and/or grazing on:
    a. White pine forest lands having loess soil in the Columbia Basin.
    b. Larch forest lands having glacial silt soil in the Columbia Basin.
    c. Subalpine range having dolomitic soil in the Missouri Basin.
2. How to restore control of summer storm runoff and soil stability on:
    a. Subalpine range having dolomitic soil in the Missouri Basin.
    b. Sagebrush-grass range having soft sediment soil in the Missouri Basin.
    c. Low shrub-shortgrass range having hard sediment soil in the Missouri Basin.
3. How to increase summer streamflow without increasing damaging peak flow discharges or sediment on:
    a. Lodgepole pine forest lands having dolomitic soil in the Missouri Basin.
    b. Subalpine range having dolomitic soil in the Missouri Basin.
    c. Spruce-fir forest having dolomitic soil in the Missouri Basin.

Though research is needed on all of the problems and in all of the problem areas listed above, and an acceptable research program would involve studies on each, a somewhat more modest program of research must be settled for at this time. It is proposed to limit the program for the immediate future to the following efforts:

1. Initiate work in white pine forest including:
    a. Analysis of existing data on snow hydrology from Priest River Experimental Forest.
    b. Selection and reservation of experimental watersheds for future investigations.
    c. Plot studies of interception, evaporation, and melting effects on soil moisture regime.
2. Assist the Northern Region in development of guides for applying runoff and erosion control measures on roads and logging areas based on information currently available or to be collected by the region.
3. Develop plans for initiating water-yield studies in lodgepole pine forest, including:
    a. Selection and reservation of experimental watersheds.
    b. Plot studies on snow hydrology under various forest stand conditions.
4. Develop plans for a study of methods for restoring depleted subalpine-grass-forb ranges.

It is obvious that this proposed program does not provide for complete development and evaluation of management practices needed to meet desired watershed management objectives in even one problem area of the region. However, it should provide a foundation for more intensive effort as more adequate research facilities become available.

# WATERSHED MAINTENANCE

## Streamflow Characteristics of a White Pine Watershed

Snowmelt is responsible for high spring volumes of streamflow from watersheds of the upper Columbia River Basin. Rapid melting of deep snow, especially when accompanied by heavy rainfall, permits large quantities of water to enter the soil mantle rather quickly. In some instances the amounts exceed the soil storage capacity and bleed out rapidly. Water thus released finds its way to stream channels more quickly than water that travels through the soil to deeper aquifers. This can cause floods. The Columbia River flood of 1948, one of the worst ever to occur in the Northwest, was caused in this way. Such flood-producing conditions can develop even on heavily timbered watersheds in good condition. To what extent the peak flood stages from such watersheds can be altered by timber harvest practices is a problem requiring research. Before these effects can be accurately evaluated, however, better knowledge is needed about the streamflow characteristics of timbered watersheds that are relatively undisturbed. A contribution to such knowledge was made during the past year by analysis of 16 years of streamflow records from Benton Creek, a 950-acre white pine forested watershed in northern Idaho, and one of the few, small gaged forest watersheds in the northern Rocky Mountains.

During the period of record, from 1939 to 1955, average annual precipitation on this watershed was 39.34 inches. Mean annual runoff during the same period was 14.93 inches and ranged from 6.01 to 21.70 inches. Instantaneous discharges ranged from a low of 0.104 to a high of 16.035 cubic feet per second square mile. Two-thirds of the runoff occurred in April, May, and June, and maximum instantaneous discharges occurred in May in all but three of the years of record.

Summer streamflow resulted almost entirely from ground water depletion, the effects of summer rains being negligible. Mean summer flow of 1.47 inches was only slightly more than the ground water discharge of 1.35 inches determined from normal depletion curves for this watershed.

A multiple linear correlation was developed relating annual streamflow to four variables: (W) winter precipitation, (F) spring and fall precipitation, (S) summer precipitation, and (R) antecedent September runoff, all expressed in inches. The equation derived was:

$$\text{Streamflow} - .983W + .722F + .144S + 27.92R - 23.56$$

Using this equation, the average annual streamflow from Benton Creek during the 44-year period, 1911 to 1955, is estimated to have been 25.0 inches.

During the summer and early fall, diurnal fluctuations in streamflow on the order of 2 percent of the daily discharge were created by variations in evaporation and transpiration rates of streamside vegetation.

## Soil Disturbance from Timber Harvesting

Maintenance of soil mantle stability is a problem of increasing concern on the steep ponderosa pine lands of southwestern Idaho. Expansion of timber harvest activity is baring more and more of the loose granitic soil that characterizes this area. Baring of soil is usually accompanied by impairment of infiltration and, hence, by accelerated storm runoff and erosion. It is highly desirable to know how to harvest timber from these lands with a minimum of sediment production. Needed for this is knowledge of the amount of soil laid bare by different cutting systems and logging methods. Some information in this connection has been obtained from a study of ponderosa pine production in the Boise Basin Experimental Forest.

The amount of soil bared by harvesting timber from 35 logging compartments was closely related to the number and volume of trees removed. Timber was cut on some compartments by single tree selection and on others by group selection. With an increase in intensity of timber cut by single tree selection from 2,000 to 7,000 trees per square mile, the amount of soil bared increased from 46 to 131 acres per square mile. With similar increases in intensity of cut by group selection, the amount of bared soil increased from 34 to 89 acres per square mile. Greater dispersion of trees cut and less repeat usage of skidtrails is believed to be the cause of more bared area on single tree selection compartments.

In compartments cut by single tree selection and logged by small tractor, an increase in intensity of cut from 2,000 to 7,000 trees per square mile increased the area bared as haul roads from 38 to 112 acres per square mile. The amount bared as skidtrails, however, remained about constant at 12 acres per square mile. Under logging by large tractor, the amount of soil bared as haul roads was essentially constant at 26 acres per square mile regardless of intensity of cut; but increased cutting increased the amount bared as skidtrails from 31 to 96 acres per square mile.

In group selection compartments there was no significant differences in the amounts of area bared due to differences in tractor size. With increase in cutting intensity from 2,000 to 7,000 trees per square mile of soil bared as haul roads increased from 23 to 48 acres and, as skidtrails, from 20 to 45 acres per square mile.

These findings indicate that group selection timber cutting is superior to single tree selection for minimizing soil disturbance. Under group selection cutting it also appears that no particular advantage is gained by using one size of tractor in preference to another.

## Control of Sediment from Logging Roads

The problem of keeping sediment out of streams flowing through forested sections of the Station territory is becoming acute, especially on the loose granitic soil in southwestern Idaho. Rapid extension of logging road systems onto steeper headwater lands has been attended by an increase in surface runoff and erosion from bared roadbeds and steep cut and fill slopes. Stepped-up deposition of sediment in stream channels points to a need for better road location and construction criteria to control runoff and maintain soil stability.

A previous annual report indicated that road gradient and length of slope on which runoff accumulates are critical variables affecting erosion on road surfaces. It also suggested some tentative standards for spacing of cross drainage on roads with granitic soil surfaces to prevent rill and gully erosion. Such measures, though generally adequate for this purpose, have not always been satisfactory for safely disposing of drainage water running from road surfaces. It was noted frequently that storm runoff diverted from road surfaces had sufficient eroding power to cut into fill or natural slopes below roads and to carry suspended material down these slopes for long distances. In some instances sediment emptied into stream channels; in others it stopped short of the channels, having been retarded or trapped on watershed slopes above the streams.

To develop better criteria for locating roads that will prevent sediment from reaching streams or other roads in a system, steps have been taken to examine and test the effects of roadway characteristics believed to exert influence on sediment movement. The characteristics that appear to have significant effect on the distance to which sediment can be carried below a road are the number of major obstructions below the road, the spacing between cross ditches on a road surface, the road gradient, and the embankment slope length. These factors have been combined into an equation for predicting sediment flow distances. Though further testing is needed, it is hopeful that this information will prove useful as a guide for determining the distance from a stream that a road can be safely located to control sediment.

## WATERSHED RESTORATION

### Effects of Plowing and Seeding on Subalpine Range

Depleted subalpine-herbaceous ranges continue to be a source of damaging summer storm runoff and erosion in numerous locations throughout the Station territory. In the past few years several range improvement projects have been initiated to increase grass production and to gain better control of runoff and erosion from such areas. One of these projects is located in the head of Manti Canyon on the Manti-LaSal National Forest. Here, 1,000 acres of moderately depleted range were closed to grazing in 1952 and treated by plowing and seeding. The area was protected from livestock grazing until 1956. Included in the treated area were paired one-half acre plots on several sites. One plot of each pair was not treated.

During the 3-year period following this treatment, total ground cover on the treated plots, including live plants and litter, did not change significantly from that on the untreated ones. The composition and volume of forage production, however, was drastically changed. There was about 5 times more grass and only 40 percent as much forb cover on the treated sites as on the untreated areas. Forage production on the treated sites (1,551 pounds per acre) was nearly twice that (848 pounds per acre) on the untreated ones.

Surface runoff, soil erosion, and infiltration rates on the treated sites were not significantly different from those on the untreated areas. However, on both kinds of sites, runoff and erosion decreased with increased amounts of ground cover. Infiltration rates were about twice as great on areas having above-average ground cover than on those with below-average cover. Additional tests are planned as it is expected there will continue to be further changes in the density of vegetation on the treated sites.

During the summer of 1956 the area was reopened to livestock grazing use. Grazing exclusion cages were installed on both treated and untreated areas. This will permit comparison of forage production and hydrologic characteristics under continued protection with these same characteristics under grazing use. It is hoped that findings from this phase of the study will prove useful as criteria for determining safe grazing use on this range.

## Evaluation of Restoration Measures on Pleasant Creek Watershed

In 1955 the Manti-LaSal National Forest and the Soil Conservation Service cooperated on a watershed improvement project in the Pleasant Creek watershed in central Utah. The Station assumed responsibility for planning and supervising an evaluation study of the upstream improvement measures employed. The study was intended to determine the effects of protection from grazing, reseeding, and contour trenching on the forage production and hydrologic characteristics of subalpine-herbaceous, mountain brush, and pinyon-juniper range sites.

Prior to treatment, infiltrometer tests were made on these sites. They show definitely inverse relationships between amounts of ground cover and storm runoff and erosion. Ground cover on the subalpine-herbaceous plots averaged 70 percent. Runoff created by 3 inches of applied rainfall on these plots averaged 40 percent and eroded soil ranged from zero to 9,344 pounds per acre. On mountain brush plots ground cover averaged 23 percent, runoff was 62 percent, and eroded soil ranged from 472 to 10,518 pounds per acre. The most depleted plots were those on pinyon-juniper range where ground cover averaged 13 percent. These plots also produced the largest amounts of runoff and erosion. Runoff averaged 74 percent and eroded soil ranged from 977 to 14,372 pounds per acre.

Gully control runoff plots equipped with sediment basins have been installed on several paired areas. One of each pair was untreated, the other contour trenched to determine the effects on runoff and sediment where erosion has reached the gully stage. During the past year area-capacity measurements were made of the sediment basins. This sets the stage for periodic repeat measurements to evaluate the effects of such treatment on sediment production.

## Cover Restoration on High Elevation Range in Idaho

On July 23, 1955 a violent flood discharge occurred in Sulphur Creek, a tributary of the Middle Fork of the Salmon River in Idaho. The flood originated on badly deteriorated subalpine range on the slopes of Morehead Mountain. During the past year the Boise National Forest has constructed many miles of contour trenches to control surface runoff from future storms likely to cause a repetition of this flood.

The Station is cooperating in the watershed improvement project in two ways: One is to determine the effects of various strengths of fertilizer application on ground cover production of the newly seeded trenches. The other is to determine the rate of plant recovery on strips of native range between contour trenches where grazing has been eliminated. Some strips were left to natural recovery, some were fertilized, some reseeded, and some both reseeded and fertilized. Permanent line transects have been established to measure conditions of ground cover and plant composition on these strips at periodic intervals. Measurements prior to treatment show that the ground cover had been depleted to between 18 and 42 percent. Repeat measurements are scheduled for 1958.

## WATERSHED IMPROVEMENT

The currently prolonged drought in the southern part of the Station territory has made an already acute water supply problem even more critical. It has focused attention on the need to reconsider all possible sources and means for obtaining more water, including increase of streamflow from mountain watershed lands. On the other hand, rapid expansion and mounting costs of water storage projects have aroused new concern about the need for preventing sedimentation by control of erosion on upstream watersheds. How to make more useful streamflow and, at the same time, maintain effective control of storm runoff and erosion on the same area pose difficult technical problems because the hydrologic conditions needed for these objectives are generally different. Chiefly involved are questions of how and to what extent, if any, plant cover requirements for maintaining soil mantle stability can be safely compromised with those required for increasing water yields. Several studies are currently under way on this problem.

### Cover Depletion Effects on Water Consumption

Restoration of plant cover on flood-source areas in Parrish Creek basin of the Davis County Experimental Watershed appears to have reduced snowmelt discharges as well as prevented recurrence of summer rain mud-rock floods. During the past year a cooperative study was undertaken with the School of Forestry, Range, and Wildlife Management of the Utah State Agricultural College to find out how and why water yields from former flood-producing areas may be altered by restoration of plant cover. The study is designed to compare soil mantle moisture conditions on aspen, brush, and herbaceous sites now in a restored condition with comparable areas on which flood-source conditions will be recreated by removing or drastically depleting the vegetation.

Of interest, as well as importance, is the method that will be employed for obtaining soil mantle moisture data. These measurements will be made with a portable neutron scattering unit developed by the Soils Department at Utah State Agricultural College. This unit registers the concentration of hydrogen ions in the soil, which is largely dependent upon soil moisture content. Readings can be directly converted to soil moisture determinations to test the reliability of the neutron unit. This unit, if found accurate within necessary limits, will eliminate time-consuming manual soil sampling and will be especially useful in soil-moisture studies on rocky soils often found on forest lands.

## Aspen Cutting Effects on Water Yield

Studies on Davis County Experimental Watershed have shown that removal of aspen forest may effect a saving of as much as 4 inches of water in the soil mantle by reducing transpirational consumption. A new study has been started on this watershed to determine the actual effects of such savings on amount and timing of streamflow. For this purpose, two aspen-forested subwatersheds of 137 and 218 acres in size have been selected. These two watersheds are being gaged to determine their relative streamflow characteristics in an undisturbed condition. When these relationships have been sufficiently well determined to permit prediction of streamflow characteristics on one from those of the other, the timber on one will be cut and streamflow measurements continued so that the effects of cutting can be evaluated.

## Effects of Snowdrifting and Cover Condition on Streamflow

The acuteness of the water supply problem that has developed in south-central Utah has intensified research efforts to discover ways and means of improving water yields in that area. If water in the form of snow can be stored on high-elevation range watersheds in such a manner that melting is substantially retarded, it is reasonable to expect a lowering of spring peak runoff and a strengthening of later season water yields. Studies on subalpine range in central Utah show that trapping of snow into drifts behind fences is physically feasible and that drifts so induced persist for as much as 2 weeks longer than snow on adjacent undrifted areas.

A new study has been started on this type of range to determine the actual effects of induced drifting on streamflow. Two 300-acre watersheds on the rim of the Wasatch Plateau have been selected for this study. These two watersheds, previously equipped with flumes for recording streamflow, have been reequipped with weir sections to improve the accuracy of streamflow records. A detailed plant cover and soil survey has been made of these two watersheds as a basis for planning snowdrifting locations and evaluating the effects of different range cover conditions on interception and soil moisture storage characteristics. Normal snowdrifting on both of these watersheds is being observed and streamflow calibrated preparatory to applying snowdrifting measures on one of the watersheds for streamflow improvement.

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# PUBLICATIONS

B. Publications in scientific and professional journals, etc.

ANDERSON, I. V. 1956. Properties, uses, and production of Engelmann spruce (*Picea engelmannii*). Forest Prod. Jour. 6: 307-311.

Explains the rise in production of Engelmann spruce from about 35 million board feet per year to nearly 500 million resulting from salvage of major bug-infested areas; describes the properties and uses of this versatile species; and forecasts the future place of the species in the western timber economy.

BINGHAM, R. T., A. E. SQUILLACE, and R. F. PATTON. 1956. Vigor, disease resistance, and field performance in juvenile progenies of the hybrid *Pinus monticola* Dougl. x *Pinus strobus* L. Zeitschrift für Forstgenetik und Forstpflanzenzüchtung 5(4): 104-112.

Juvenile performance of 16 different hybrid progenies from controlled pollinations between blister rust-resistant selections of eastern and western white pines is discussed in detail. Hybrids usually showed definite hybrid vigor and less resistance to rust than corresponding intraspecies crosses. The degree of hybrid vigor and rust resistance of a hybrid progeny seems to depend upon the superiority of the individual parents chosen in making the cross.

BLAISDELL, JAMES P., and WALTER F. MUEGGLER. 1956. Effect of 2,4-D on forbs and shrubs associated with big sagebrush. Jour. Range Mangt. 9(1): 38-40.

Authors describe effects of 2,4-D spray, used for the control of big sagebrush, upon 38 forbs and 15 shrubs and trees occurring in sagebrush stands of eastern Idaho.

BLAISDELL, JAMES P., and WALTER F. MUEGGLER. 1956. Sprouting of bitterbrush (*Purshia tridentata*) following burning or top removal. Ecology 37(2): 365-370.

The amount and nature of sprouting of bitterbrush after burning and after top severance by cutting is discussed. Study suggests that ability of plant to sprout in certain areas is influenced both by genetic and environmental factors.

BOE, KENNETH N. 1956. Regeneration and slash disposal in lodgepole pine clear cuttings. Northwest Sci. 30(1): 1-11, illus.

Relationships of cutting, seed supply, and slash disposal methods to fire hazard reduction and seedling establishment on different seedbeds were studied in lodgepole pine clear cuttings for 5 years in central Montana. The main seed supply for regenerating clear cuttings is in the cones attached to the slash or scattered over the ground. Only small, uncertain amounts of seed were dispersed beyond 3 chains from the uncut timber edge into the clear cuttings. Large numbers of seedlings per acre and high rates of stocking were found on skidroads and on forest floor, scarified, and lopped and scattered seedbeds. Unburned slash windrows and other concentrations were moderately stocked while stocking on seedbeds resulting from burning of slash in piles and windrows was low. Of the four slash disposal methods tried--burning in windrows and concentrations, bulldozer piling and burning, lopping and scattering, and no disposal--only the first two reduced fire hazards to acceptable standards. Both of these methods are also satisfactory for regeneration providing burned spots are restricted to one-twentieth acre or less in area and cover no more than 25 percent of the total area cut.

CALHOUN, E. L., H. R. DODGE, and R. W. FAY. 1956. Description and rearing of Dendrophaonia scabra (Giglio-Tos) (Diptera, Muscidae). Ann. Ent. Soc. Amer. 49(1): 49-54.

The rearing of this fly in the laboratory is explained. The eggs, larvae, and pupae are described and figured.

COPELAND, OTIS L., JR. 1956. A study of the influence of certain factors on soil oxidation-reduction potentials. Dissertation abstracts, University Microfilms, Ann Arbor, Mich.

Effects of two moisture levels and two degrees of compaction on the oxidation reduction potentials of 17 soils over an incubation period of 8 weeks were determined. The "optimum moisture--no compaction" series maintained the highest and the "saturated-high compaction" series the lowest redox potentials throughout the incubation period.

COPELAND, OTIS L., JR. 1955. The effects of an artificially induced drought on shortleaf pine. Jour. Forestry 53(4): 262-264. (Note: Study completed before author transferred to Intermountain Station. Was not included in 1955 annual report.)

The experiment disclosed that a lack of soil moisture curtails diameter growth, shoot growth, and needle length, but needle color is unaffected. Reduction in crown density results in an over-all decrease in total nitrogen uptake. Branch dying, caused by a prolonged drought, eventually produces a much smaller crown than originally possessed by the tree.

COPELAND, OTIS L., JR. and ROBERT G. McALPINE. 1955. The interrelations of littleleaf, site index, soil, and ground cover in Piedmont shortleaf pine stands. Ecology 36(4): 635-641. (Note: Work completed in 1953, before senior author transferred to Intermountain Station. Was not included in 1955 annual report.)

This report reviews soil and plant cover conditions as determined by a soils-littleleaf survey of 158 Piedmont forest stands consisting mainly of second-growth even-aged shortleaf pine.

DODGE, H. R. 1956. Tussock moth threatens timber. West. Conserv. Jour. 13(1): 36, 40, 42-43, 45, 50.

The life history of the Douglas-fir tussock moth is described, the important outbreaks reviewed, and mention is made of current studies being undertaken to predict the trend of the current outbreak in northeastern Washington.

DODGE, H. R. 1956. New North American Sarcophagidae, with some new synonymy (Diptera). Ann. Ent. Soc. Amer. 49(2): 182-190.

Two new genera and four new species of sarcophagid flies are described. A key is presented to species of Chaetoravinia and several new synonymies are published.

DODGE, H. R. 1956. A new sarcophagid genus with descriptions of fifteen new species (Diptera). Ann. Ent. Soc. Amer. 49(3): 242-263.

The genus Idoneamima is created for 19 species of sarcophagid flies from eastern North America. Fifteen of the species are described as new, the others are removed from Sarcophaga. The male genitalia are figured and two keys to the separation of the species are presented.

DODGE, H. R. 1956. Two new Sarcophagid flies from Cuba (Diptera). (Intended for publication in "Revista de la Soc. Felipe Poe" in Cuba.) Memo de la Soc. Cubana de Hist. Nat. Vol. 23 No. 1: 97-103, illus.

Description of two new species of sarcophagid flies with figures is presented.

FOILES, MARVIN W. 1956. Effects of thinning a 55-year-old western white pine stand. Jour. Forestry 54(2): 130-132.

Thirty-year results indicated that light thinning had little effect on total volume production but enhanced the value of the stand by increasing the proportion of high-value white pine and by stimulating diameter growth of dominant and codominant stems.

HAUPT, HAROLD F. 1956. Nitrogen loss from granitic soils on cheatgrass brome range. Forest Sci. 2(4): 268-272.

Nitrogen content of the surface 0.5 inch of soil on cheatgrass brome range in south Idaho was found to vary directly with amount of plant and litter cover. Nitrogen losses caused by runoff from summer storms were greatest from depleted sites. Losses from sites disturbed by trampling were more than double those from undisturbed sites.

HOLMGREN, RALPH C. 1956. Competition between annuals and young bitterbrush (*Purshia tridentata*) in Idaho. Ecology 37(2): 370-377.

Control of competing vegetation on an annual-weed type was found to be requisite to establishment of artificially seeded bitterbrush on a deer winter range. Where the competitors were broadleaved summer annuals, growth rate of bitterbrush seedlings was reduced and first-season mortality much higher than on weed-free, but otherwise similar, sites. Where the competitor was the winter-annual cheatgrass, virtually all bitterbrush seedlings died within a few weeks after emerging.

HOLMGREN, RALPH C., and JOSEPH V. BASILE. 1956. Range revegetation and deer on the Payette. Idaho Wildlife Review 9(2): 10-13.

An important factor adverse to establishment of bitterbrush by artificial planting on a deer winter range is the deer herd itself.

LEAPHART, CHARLES D. 1956. Physiological studies of some fungi associated with pole blight of western white pine. Mycologia 48: 25-40.

The report gives the prerequisites of growth of five fungi, four isolates of Leptographium sp. and one isolate of Ceratocystis pilifera, isolated from pole blighted trees.

MARSTON, RICHARD B. 1956. Air movement under an aspen forest and on an adjacent opening. Jour. Forestry 54(7): 468-469.

Anemometer measurements made under an aspen forest canopy and on an adjacent grassy opening at 8,200 feet elevation showed that the aspen cover caused an average wind velocity reduction of 2.6 miles per hour and a relative reduction of 79 percent as compared to velocities in the open.

MIELKE, JAMES L. 1956. The rust fungus (Cronartium stalactiforme) in lodgepole pine. Jour. Forestry 54(8): 518-521.

Contains information on the fungus designed to aid in its field recognition. Nomenclature of the organism, its hosts, range, character of attack on lodgepole pine, and the damage caused by it are discussed.

PARKER, D. E. 1956. The effects of DDT on wildlife. Idaho Wildlife Review 8(16): 5-7.

A brief review is given of the background of research into effects of DDT on wildlife prior to its extensive use in controlling forest pests.

ROE, ARTHUR L. 1956. The effect of competition in old-growth western larch--Douglas-fir stands. Montana Acad. Sci. Proc. 16: 41-45.

Reports an attempt to investigate quantitatively the effect of root competition by the understory on an overstory of larch and Douglas-fir. Removal of the understory resulted in a significant increase of growth in the overstory western larch but not in the Douglas-fir. Effects of these results on management practices are discussed.

SCHOOF, H. F., E. P. SAVAGE, and H. R. DODGE. 1956. Comparative studies of urban fly populations in Arizona, Kansas, Michigan, New York, and West Virginia. II, seasonal abundance of minor species. Ann. Ent. Soc. Amer. 49(1): 59-66.

Records of abundance and months of occurrence of the minor species of flies trapped in the above-named states are presented.

SMITH, EDWARD W. III, ELBERT CLEAVELAND, and DONALD W. LYNCH. 1956. A guide for finding superior ponderosa pine trees and stands in southwestern Idaho. Southern Idaho Forestry Association, Inc.

Defines for laymen certain genetics terms; gives instructions for selecting and reporting "plus" ponderosa pine trees.

C. Processed reports.

ANDERSON, I. V. 1956. Engelmann spruce: Its properties, uses, and production. Research Paper 39, 16 pp.

Explains the rise in production of Engelmann spruce from about 35 million board feet per year to nearly 500 million resulting from salvage of major bug infested areas; describes the properties and uses of this versatile species; and forecasts the future place of the species in the western timber economy.

BASILE, JOSEPH V., and RALPH C. HOLMGREN. 1956. Artificial revegetation studies on depleted big-game winter ranges in Idaho. Job Completion Reports, Project W 111-R-2. Idaho Fish and Game Dept., 19 pp.

Cost of seeding bitterbrush on steep slopes; results of the bitterbrush seeding-depth study; a comparison of 3 chemicals as protectants of sown bitterbrush seed against rodent depredation; and effects of game on browse revegetation efforts are given.

BOE, KENNETH N. and DAVID TACKLE. 1956. Board-foot increment on residual ponderosa pine in Montana. Research Note 34, 7 pp.

A harvest cutting study established in 1932 in western Montana relates board-foot growth to three different levels of reserve in mature ponderosa pine on Site Index 70. Twenty-year records disclose that 4,000 to 8,000 board feet per acre of vigorous, well-spaced trees between 120 and 220 years old and of moderate size, comprised a satisfactory reserve. A table showing individual tree growth during the 20-year period by diameter, vigor, and intensity of cutting is presented for ponderosa pine and Douglas-fir.

COLE, W. E. 1956. Biological observations on the pine butterfly during an outbreak in southern Idaho, 1953-1954. Research Note 29, 8 pp., illus.

Observations on the life history and habits of the pine butterfly are given and descriptions and illustrations of different developmental stages are presented.

COLE, W. E. 1956. Surveys and control methods of the pine butterfly during an outbreak in southern Idaho, 1953-1954. Research Note 30, 9 pp. and map, illus.

Methods are described for sampling populations of pine butterfly prior to aerial spraying and for determining mortality following spraying.

COPELAND, OTIS L., JR. 1956. Watershed management in research-soil survey needs. Proc. Watershed Management Conference, Northern Region, pp. 36-43.

A discussion of the needs for and the interpretation and utilization of soil survey information in relation to watershed management, engineering, timber management, and other activities.

COPELAND, OTIS L., JR. 1956. Preliminary soil-site studies in the western white pine type. Research Note 33, 4 pp.

The results indicate a strong relationship between certain easily determined soil characteristics and site index of western white pine. The significant relationships between site index of commonly associated species in the white pine forest type also provide means for estimating the probable site index from other species on the same site.

CRADDOCK, GEORGE W. 1956. Status of present knowledge and present watershed research program of the Intermountain Station. Proc. Watershed Management Conference, Northern Region, 106 pp.

Discusses and presents diagramatically the kind of knowledge that has been developed so far in watershed management research and specifically how that knowledge is applicable to forest and range lands of the Intermountain Region. Also reviews current watershed problems and research programs in the Region 4 portion of the Station territory.

DIVISION OF FOREST ECONOMICS. 1956. Economics research needs related to wild land management and development in the mountain states. Research Paper 38, 27 pp., illus.

A review of resource problems in the Rocky Mountain States that warrant economic analysis is given. Covers individual problems in timber, range, water, and wildlife management. Problems in marketing and area management are also covered. Contains a general description of the whole area and briefer descriptions of each problem.

FOILES, MARVIN W. 1956. Time required to prune crop trees in the western white pine type. Research Note 32, 4 pp.

Summarizes the time required to prune crop trees in two western white pine stands and one mixed stand dominated by grand fir. The average production ranged from 37 trees per man-day in a fairly open white pine stand to 16 trees per man-day in a dense, brushy, mixed stand.

HERRINGTON, ROSCOE B. 1956. Montana Christmas tree shipments drop slightly. Research Note 28, 4 pp.

Gives numbers of Christmas trees shipped from various Montana counties by rail and truck, and numbers shipped to most important state markets. Also, shipments are compared with previous years.

HERRINGTON, ROSCOE B. 1956. Northern Rocky Mountain pole production in 1955. Research Note 37, 4 pp.

Numbers of poles produced in 1955 in Montana, north Idaho, and northeast Washington are presented. Production by species and source is also given. Proportions by length and A.S.A. class are shown. Comparisons are made with production in previous years.

ISRAELSON, MARGUERITE A. 1956. Publications of the Intermountain Forest and Range Experiment Station, 1953 through 1955, and the Northern Rocky Mountain Forest and Range Experiment Station, 1951 through 1954. Research Paper 29 (Supp.), 35 pp.

This supplement brings up to date as of 1955, the publications of the consolidated Stations.

MIELKE, JAMES L. 1956. A needle cast of lodgepole pine caused by the fungus Hypodermella concolor. Research Note 27, 3 pp.

The fungus is now epidemic and spreading in the Intermountain region. Its distribution, hosts, symptoms, life history, and character of damage are briefly outlined.

MOESSNER, KARL E. 1956. Combined vertical and horizontal stereograms. Research Note 36, 3 pp. illus.

Presents a series of stereograms of forest conditions combining vertical aerial views with horizontal pairs taken with a stereo camera. Describes how to prepare these stereograms.

MOESSNER, KARL E. 1956. A parallax wedge for mountainous areas. Research Note 39, 2 pp. illus.

Presents a new parallax wedge for measuring heights on aerial photographs of areas of large elevational variations.

MOESSNER, KARL E. 1956. Aerial photo scale-protractors for mountainous areas. Research Note 40, 7 pp. illus.

A redesign of aerial photo protractors to give a range of scales more suitable for use on photography having wide variations in scale as well as providing a more readable protractor is presented.

MUEGGLER, WALTER F. 1956. Is sagebrush seed residual in the soil of burns or is it wind-borne? Research Note 35, 10 pp.

Concludes that sagebrush seedlings on burned areas arise both from seed introduced from adjacent unburned sources and from seed stored in the soil that remains viable after burning. Residual seed appears to be the greater source of seedlings on the major portion of large burns.

PACKER, PAUL E. 1956. Watershed management problems and research needs in the Region 1 area. Proc. Watershed Management Conference, Northern Region. 106 pp.

Presents a preliminary analysis of watershed management problems and delineates important problem areas in northeastern Washington, northern Idaho, and Montana. Characteristics of Region 1 watershed lands giving rise to problems are discussed and kinds of research needed to provide solutions are suggested.

PLUMMER, A.PERRY, and ROBERT L. JENSEN. 1956. Artificial revegetation studies on big-game ranges in Utah. Job Completion Reports, Project W 82-R-1. Utah Fish and Game Dept., 26 pp.

Growth and survival of shrub plantings using planting stock, wildings, stem cuttings, and seedling transplants; seed acquisitions, site classification; germination techniques; and methods of site preparation and planting are included. Gives results from March 1, 1955 to March 1, 1956.

TACKLE, DAVID. 1956. Stocking and seedbed distribution on clean-cut lodgepole pine areas in Utah. Research Note 38, 3 pp.

Reproduction and seedbed distribution were sampled on 6-year-old clean-cut areas in the Uinta Mountains of northeastern Utah where the logging slash had been lopped, scattered, and left unburned. Adequate stocking of lodgepole pine occurred only on seedbeds classified either as slash under 1 foot deep, disturbed duff, or disturbed mineral soil. Seedbeds not conducive to seedling establishment were slash over 1 foot deep, undisturbed duff and soil, and grass and brush. The study substantiates earlier observations that burning of slash is not essential for successful establishment of lodgepole pine on clean-cut areas.

TAYLOR, ROBERT E. 1956. Some properties of 144 soils from three Intermountain States. Misc. Pub. 7, 15 pp.

Presents basic data on the chemical and physical properties of 144 soils from Utah, southern Idaho, and eastern Nevada. Properties were determined from bulk samples and 2-inch cores in the upper 18 inches of the mantle. Properties tested included mechanical composition, organic matter, stone content, free carbonite content, pH reaction, and plasticity constants.

WASHBURN, R. I. 1956. Electronic recorder as aid in aerial insect surveys. Research Note 31, 3 pp., illus.

Reports on tests of a dictating machine used in aircraft during aerial insect surveys with description and illustrations of equipment.

WILSON, ALVIN K. 1956. The Boise Basin Experimental Forest for better forest management. Misc. Pub. 8, 26 pp., illus.

A guide book which outlines past and current research activities on the experimental forest.